REPORT 52

SWEEP

SOIL AND WATER
ENVIRONMENTAL
ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION
DU MILIEU PEDOLOGIQUE
ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD SCALE TESTS OF COVER CROPS I AND II

FINAL REPORT

May, 1992

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EXECUTIVE SUMMARY

During 1990-1991 three separate field scale cover crop trials were conducted in Middlesex, Perth and Huron counties in southwestern Ontario. The first trial looked at broadcasting barley and annual ryegrass into corn when the corn was at approximately the twelve leaf stage. This study was located at five locations, two of which were managed in an organic fashion and the remaining sites were band sprayed. The second area of study looked at seeding spring cereals (oats and barley) into soybeans at 10% leaf drop and prior to harvest. A total of five cooperators participated in this part of the study. The following year, 1991, the best performing treatments from the forementioned studies were carried one step further. This trial examined seeding rates of 1/2X, 1X and 2X the recommended rate for annual ryegrass broadcast into corn and barley and oats seeded into soybeans at 10% leaf drop. A total of nine sites were involved in this project.

More than adequate rainfall was received around the time of cover crop application in 1990. However in 1991 insufficient precipitation levels were recorded at this time which had a dramatic effect on the performance of the cover crops, especially the annual ryegrass.

In both years, the spring cereals applied into soybeans at 10% leaf drop at the recommended rate increased residue levels by late fall relative to soybean stubble alone. Oats performed slightly better than barley in 1990 with the opposite occurring in 1991.

Practical considerations related to labour needs, weather and the timing of cover crop establishment for adequate fall growth did not favour the planting of spring cereals prior to soybean harvest.

In the first year annual ryegrass underseeded into corn produced considerably more top growth than either of the barley treatments by late fall. Due to lack of rainfall the annual ryegrass treatments in the second year performed at less than a satisfactory level.

The soybeans were slightly damaged at time of application as the cooperators tractor, mounted with a seed broadcaster, was used to apply the seed. The main crop yields in the cover crop establishment year or the subsequent year were not significantly affected by any of the cover crop treatments.

Taking into consideration residue levels, rainfall simulation results and seed costs the annual ryegrass applied at the recommended rate of 15 kg/ha would be the choice of most producers.

ACKNOWLEDGEMENTS

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CMS extends its appreciation for the assistance of those producers cooperating in the study.

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1.0 INTRODUCTION

It is our understanding that the Technology Evaluation and Development (TED) subprogram of SWEEP was established to facilitate the evaluation of existing technologies and the adaptation of such technologies for soil conservation and phosphorus (P) load reduction purposes. It is intended that TED-sponsored investigations should be undertaken mainly at field scale and within commercial farming operations.

An important objective of this subprogram is the involvement and close cooperation of the farming community in the process of developing and refining technologies and systems. Through this involvement it is expected that the results of TED-sponsored research will be directly applicable to important problems and needs faced by farmers as they attempt to deal with soil degradation. Rapid adoption of such technologies will be necessary for SWEEP to realize its phosphorus reduction goals within the specified time frame.

Because of the high proportion of P loss that occurs during spring freshet, especially in row crop fields, it is desirable to achieve a temporary vegetative cover over winter and during spring runoff to hold the soil in place. Added organic material from these cover crops may also benefit soil stability and productivity. In addition cover crops assist in the recycling of nutrients and when managed appropriately can reduce the amount of types of pesticides used within a crop rotation. These attributes of cover crops make them an attractive management option in sustainable agricultural systems.

Efforts by researchers and innovative conservation farmers to develop effective cover crop management systems have made significant progress. Numerous questions regarding the best species/varieties, application and kill methods and timing have been answered. It is the intent of the TED cover crop studies outlined herein to allow for a continuation of the second phase of the screening and testing of field plot research which is the application of cover cropping at the farm level.

The field scale tests incorporate those treatments that have shown promise at the research plot scale and may also be accepted by producers. The field scale demonstrations also serve as a way to transfer information to extension personnel as well as innovative farmers. In turn, these people will transfer the information to other producers.

In order to make relatively rapid progress in our understanding of this area and the

subsequent adoption of suitable practices, it is important to work with existing crops where the basic management techniques are widely known and practised. It is also important to work with those alternatives that provide an adequate level of erosion control and are relatively inexpensive to implement or have an added value to the subsequent crop.

In order for a producer to accept and use cover crops the following criteria should be met:

1) ease of planting the cover crop;
2) little or no harm to the current crop when seeding the cover crop;
3) little or no effect on current or future crop yield;
4) time and cost effectiveness.

With the above criteria in mind, we continue our search for the best cover crop that can be used.

Once established, a cover crop has the potential to provide enough cover to protect the soil against erosion when the ground would otherwise not be covered. Various planting dates, rates of application and methods of establishment can affect the relative amount of soil erosion control. The use of an early planting date (e.g. July) may be beneficial on row crops, especially corn where erosion also occurs during the growing season (Swanton, pers. comm.).

The abundance of home-grown and commercial cereal grain seed makes it an attractive option as a potential winter cover crop. Using the mulch provided by the natural senescence of leaves or the mulch produced by the chaff during the combining of beans could aid in the rapid establishment of cereal cover crops between beans and corn in a rotation. Previous research by this worker has shown that, in general seed broadcast at 10% leaf drop or at harvest in soybeans produces the best overall effect in relation to dry matter, soil residue cover and corn grain yield. Problems with allelopathic effects and the extra expense of chemically killing a winter cereal in the spring make spring cereals a more economical alternative.

Integrated weed management has become a familiar term in the recent past as there is a growing public concern about the impact of agricultural chemicals on non-target organisms and potential environmental contamination. The use of cover crops may be integrated into this system as a means of competition for weeds, thus suppressing their growth and population. Swanton (pers. comm.) reports that some types of cover crops in particular

spring barley, may suppress the growth and population of winter annuals.

In addition to suppressing weeds some types of cover crops have the potential of supplying nutrients, particularly nitrogen to the following crop. Modification to the current practice of green manuring deserves investigation so it may be adapted to conventional farm management systems. If the benefit of nutrient recycling outweighs the cost of control then the use of these cover crops looks very promising.

While the use of cover crops is most conveniently associated with a no-till cropping system it is recognized that many Ontario producers will adopt some form of a reduced or minimum tillage system. With this in mind, the cover crop studies should be of value to users of either type of system.

1.1 Objectives

i) to determine the effect of cover crop management systems including species, planting date and method of application, on the growth and yield of the current and subsequent crop;

ii) to determine the effect of cover crop management systems including species, date and method of planting on the soil surface coverage between current crop and the establishment of the next crop canopy;

iii) to document the costs associated with the use of specific cover crop management systems on a field scale;

iv) to prepare general recommendations for management of cover crop systems with regard to species, date and method of planting;

v) to evaluate the response of cooperating producers and extension workers to the cover crop management systems demonstrated.

1.2 Field Scale Tests

Research sponsored by TED has increased our knowledge and experience with cover crops in Ontario. Numerous exciting ideas have been tested and promising treatments identified. As a result many options exist which merit further field scale testing. In recognition of this, several crop management practices were investigated at the field scale level by CMS. The cover crop management practices were selected with the following criteria in mind:

- soil conservation: ground cover is provided during the critical fall, winter and spring

runoff period;

- ease of management and likelihood of success: insight into the adoption process has guided the selection of the management practice;
- lack of interference with the main crop: no interference is anticipated in either the establishment year or the following year;
- within a corn-soybean rotation: four of the projects met this criterium while the fifth incorporated a very typical cash crop sequence of winter wheat followed by corn.

1.2.1 Field scale testing of soybean-spring cereal cover crop-corn management systems (1990-91)

At three of the five sites, barley and oat seed was broadcast at 10% soybean leaf drop, at the remaining sites seed was broadcast at soybean harvest. Each site also included a control area. It was proposed that the seed be applied aerially by a commercial applicator on both dates.

1.2.2 Field scale testing of corn-spring cereal and annual ryegrass cover crop-soybean management systems (1990-91)

Treatments for this part of the study included: spring barley var. Leger; spring barley var. Rodeo; annual ryegrass; and a control. The seed was applied into the corn crop at the second interrow cultivation (approximately early July). The seed was to be applied at double the recommended rate using a Gandy® spreader attachment mounted on the interrow cultivator.

1.2.3 Field scale testing of winter wheat-hairy vetch cover crop-corn management system (1990)

Hairy vetch seed was no-till drilled into winter wheat stubble in August of 1990. This experiment was designed to compare the timing of hairy vetch control (chemically controlled in fall 1990 or spring 1991) on the growth and yield of no-till corn to be planted in the spring of 1991. Ultimately the plots were abandoned. See Section 2.0 for details.

1.2.4 Field scale testing of barley, oats and annual ryegrass management systems (1991)

Seed of barley, oats and annual ryegrass were applied at 1/2X, 1X and 2X the recommended rate. A control was included at each site. Each of the species treatments were applied at three sites, for a total of nine sites. The barley and oat treatments were broadcast into soybean fields at the 10% soybean leaf drop stage while the annual ryegrass was to be applied into corn at the second interrow cultivation.

The evaluation of the success of the cover crop management systems was in terms of the following:

- establishment of the cover crop;
- provision of ground cover;
- weed control;
- effects on the current crop in the establishment year, and in the following year.

The information obtained from these and other TED sponsored projects should allow for the development of sound and practical recommendations on the management of cover crops. The results of these collective investigations and the manner in which they were obtained will assist the TED subprogram in fulfilling its objectives.

2.0 DEVIATIONS FROM THE WORK PLAN

In the first year of this study, one project looked at the use of spring cereals applied to a soybean field at either 10% leaf drop or just prior to harvest. It was first proposed that the seed be aerially applied but due to prohibitive costs and lack of cooperation with commercial seed applicators, the cooperator's tractor, mounted with a spreader, was used to apply the treatments.

The second part of the above noted study involved the broadcasting of spring cereals at soybean harvest. Inclement weather delayed soybean harvest in the fall of 1990. Thus upon consultation with Dr. D. Falk, a cereal breeder at the University of Guelph, it was recommended that six row barley varieties be used for both treatments instead of the proposed oats and barley, because of their vigour and quick growth. In addition, only two sites were used for this section of the project due to the delayed harvest instead of the proposed three sites.

It was initially proposed in the field scale testing of corn-spring cereal and annual ryegrass cover crop-soybean management systems project that a Gandy® spreader be mounted on the cooperator's interrow cultivator. Due to the unavailability of a Gandy® spreader, a Herd® gravitational flow broadcaster was used to replace it. In addition, the spreader was mounted on the cooperator's tractor and not on the intended interrow cultivator. At four of the six sites the timing of the treatment application was just after the second interrow cultivation involving an additional pass with the tractor. At one of the remaining two sites, two methods of treatment application were employed with the seed either being broadcast followed by interrow cultivation or interrow cultivation followed by seeding of the cover crop. At the remaining site the spreader was mounted on the front of the tractor which resulted in the cover crop seed being broadcast followed immediately by a pass with the interrow cultivator.

The last project proposed for the 1990 season involved drilling hairy vetch into winter wheat stubble. In mid August 1990, the cooperator completed this task. Unfortunately due to wet weather conditions before and after seeding the hairy vetch seed rotted in the soil, thus no germination or growth of the hairy vetch occurred. After discussing the situation with the client, this portion of the project was discontinued.

In 1991, the second portion of the cover crop studies was implemented. This seeding rate

was completed using the Herd® gravitational flow broadcaster. However the seeding rates were found not to be as accurate as expected even though numerous calibrations were carried out prior to cover crop application. The client was informed of this situation and requested CMS to proceed but with rate checks in place.

Unseasonably warm conditions prevailed in May and June in most parts of southwestern Ontario in 1991 which resulted in extremely rapid corn growth. A combination of delayed approval for project implementation and the advanced corn growth made it difficult to find appropriate sites. In the end, the corn at two of the sites selected were more advanced than proposed for the application of the annual ryegrass treatments.

As stated in the proposal the dry matter samples and residue levels of the cover crops planted in 1991 were to be in late fall. Due to a miscommunication between a cooperator and his father, a corn field which contained annual ryegrass treatments was moldboard ploughed before these data could be collected.

3.0 MATERIALS AND METHODS

3.1 Location and Characterization of Sites

Table 3.1.1 and Appendix A outline the location and characterization of all the sites included in the two years of study.

Soil samples were taken to determine the soil texture and fertility levels. The samples were analyzed according to the standard procedures used by the Department of Land Resource Science, University of Guelph. See Table 3.1.1 for soil texture summaries and Appendix A for soil fertility levels.

Table 3.1.1: Location and Characterization of All Sites Involved in the Field Scale Cover Crop Studies I and II, 1990-1991.

Project: Soybean-Spring Cereal Cover Crop-Corn Management Systems					
	10% Soybean Leaf Drop			Soybean Harvest	
Location	Site 1	Site 2	Site 3	Site 4	Site 5
Lot	2	16	9	20	20
Concession	6	2	6	15	15
Township	Hibbert	Stephen	Downie	Goderich	Goderich
County	Perth	Huron	Perth	Huron	Huron
Soil texture	Silt loam	Loam	Silt loam	Silt loam	Silt loam
Project: Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management Systems					
Location	Site 1	Site 2	Site 3	Site 4	Site 5
Lot	16	3	15	21	20
Concession	5	1	South Bory	16	13
Township	Caradoc	McGillivray	Hay	London	Hay
County	Middlesex	Middlesex	Huron	Middlesex	Huron
Soil texture	Loamy very fine sand	Silt loam	Fine sandy loam	Silty clay loam	Sandy loam
Project: Winter Wheat-Hairy Vetch Cover Crop-Corn Management System					
Location	Site 1				
Lot	20	Note: This cover crop study was discontinued (see Section 2.0 for details).			
Concession	15				
Township	Goderich				
County	Huron				
Soil texture	Silt loam				

Table 3.1.1: Location and Characterization of All Sites Involved in the Field Scale Cover Crop Studies I and II, 1990-1991 (Continued).

Project: Barley, Oats and Annual Ryegrass Management Systems			
Barley Treatment Sites			
Location	Site 1	Site 2	Site 3
Lot	15	20	19
Concession	8	10	8 N/2
Township	Biddulph	Lobo	London
County	Middlesex	Middlesex	Middlesex
Soil texture	Clay loam*	Clay loam*	Loam*
Oat Treatment Sites			
Location	Site 1	Site 2	Site 3
Lot	21	8	18
Concession	16	1	11
Township	London	Stephen	Lobo
County	Middlesex	Huron	Middlesex
Soil texture	Silty clay loam*	Clay loam*	Clay loam*
Annual Ryegrass Sites			
Location	Site 1	Site 2	Site 3
Lot	9	20	22
Concession	6	3	5
Township	Downie	McGillivray	Caradoc
County	Perth	Middlesex	Middlesex
Soil texture	Silt loam	Loam	Silt loam

* Soil samples not taken, therefore based on cooperator knowledge.

3.2 Experimental Design and Analysis

Each site was set up as side-by-side comparison strips of the different treatments. The projects implemented in 1990 included comparisons of barley (var. Leger), barley (var. Rodeo) and annual ryegrass broadcast into corn; barley and oats broadcast into soybeans at 10% leaf drop; and barley (six row varieties) broadcast into soybeans at harvest. Cover crop seeding rates of 1/2X, 1X and 2X the recommended rate were compared in the projects implemented in 1991 for annual ryegrass broadcast into corn and oats and barley broadcast into soybeans at 10% leaf drop. There was one strip per site of each of a control and cover crop treatment randomly located within the field.

Data were collected from four points within each treatment strip for each of the parameters with the exception of yield. Each treatment strip produced one yield value. Where

appropriate, the data were analyzed using a t-test at the 0.05 level of probability. When the sites were combined for yield each site represented one subsample. For the remainder of the parameters each of the subsampling data were combined in the t-test analysis when sites were analyzed together.

3.3 Agronomic Practices

The cover crop studies were completed over a two year period, 1990 and 1991.

The projects which involved spreading various cover crops into corn were performed from mid-June to mid-July depending on the rate of corn growth. In 1990 four of the five sites were implemented when the corn was at approximately the 12 leaf stage (0.5 to .75 m in height). The remaining site was completed when the corn was approximately 1.0 to 1.5 m in height. In 1991 one of the three sites in the annual ryegrass seeding rate trials was applied at the 12 leaf stage while the remaining two sites were implemented at more advanced corn growth stages.

In general, the sites which involved spreading spring cereals into soybeans at 10% leaf drop were implemented at the targeted time. Delays in harvesting of the soybeans in the fall of 1990 due to unfavourable weather conditions resulted in later than proposed application of the cover crops at harvest. With the exception of one site, an electric Herd® Sure-Feed Broadcaster (model I-92) mounted on the cooperator's tractor was the implement used to apply the cover crops. A rheostat was employed to control the speed of the fan on the broadcaster. Due to the nature of the spreading pattern of this type of broadcaster, variability in the seeding rates were apparent even though numerous calibrations were undertaken prior to seed application. At the remaining site a cooperator owned Vicon® spreader, which was power take-off (PTO) driven, was utilized for the cover crop work.

The farm management practices varied from cooperator to cooperator depending on the type of crop grown, soil type, weather conditions, tillage practices, etc. Tables 3.3.1 through 3.3.5 contain a summary by project of the tillage, cropping, fertilizer and pesticide practices carried out by each cooperator.

Maximum, minimum and mean daily temperatures and daily total precipitation are summarized for each site in Appendix B. This information was obtained from the Atmospheric Environment Service, Environment Canada.

Table 3.3.1: Farm Management Practices for the Field Scale Soybean-Spring Cereal Cover Crop-Corn Management Systems Listed by Individual Site. Cover Crop Studies I and II, 1990-1991.

Farm Management Practices	Soybeans at 10% Leaf Drop Sites			Soybean Harvest Sites	
	Site 1	Site 2	Site 3	Site 4	Site 5
Previous Cropping Information (1990)					
- Crop	Soybeans	Soybeans	Soybeans	Soybeans	Soybeans
- Variety	Maple Donavon	Not given	Maple Glen	Pioneer®0877	Not given
- Straw management	Chopped & spread	Chopped	Spread	Chopped & spread	Chopped & spread
Cover Crop Information					
-Date of application (1990)	September 13/90	September 28/90	September 20/90	October 20/90	October 20/90
Tillage Practices					
- Primary (1990)	None	None	None	None	None
- Secondary (1991)	None	Cultivate (3X)	Cultivate (1X)	None	None
- Post emerge (1991)	None	None	None	None	None
Current Cropping Information (1991)					
- Crop	Corn	Corn	Corn	Corn	Corn
- Variety	Pioneer® 3921	Pioneer® 3751	Pioneer® 3790	Pioneer® 3751	Pioneer® 3751
- Date	May 6/91	May 11/91	May 5/91	May 8, 1991	May 8, 1991
- Rate (seeds/ha)	74,100	64,220	69,160	66,690	66,690
- Planting equipment	No-Till Planter	I.H.®56 Planter	I.H.®800 Air Planter	White®5100	White®5100
- Attachments				½" ripple coulter ahead of fertilizer + seed openers. Residue clearing discs.	½" ripple coulter ahead of fertilizer + seed openers. Residue clearing discs.
Fertilizer (1991)					
- Pre plant	None	123 kg/ha 28-0-0	None	None	None
- At plant	67 kg/ha actual N (28%)	224 kg/ha 8-32-16	68 kg/ha 6-25-30	196 kg/ha 15-30-10	196 kg/ha 15-30-10
- Post plant	None	None	59 kg/ha actual N	134 kg/ha actual N (28%)	134 kg/ha actual N (28%)
Pesticides (1991)					
- Pre plant	Roundup® 2,4-D			1.0 l/ha 2,4-Dester + 1.5 l/ha corn oil concentrate	
- At plant	Bladex®			2.0 l/ha Dual® + 1.1 kg/ha atrazine	
- Post plant		1.2 l/ha Banvel®	1.7 l/ha Dual® 0.6 l/ha Banvel®	0.8 l/ha 2,4-Damine + 0.2 l/ha Banvel®	

Table 3.3.2: Farm Management Practices for the Field Scale Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management Systems Listed by Individual Site. Cover Crop Studies I and II, 1990-1991.

Farm Management Practices	Site 1	Site 2	Site 3	Site 4	Site 5
1990 Cropping Information					
- Crop	Corn	Corn	Corn	Corn	Corn
- Variety	Pioneer®3737	Pride®299	Pioneer®	Co-op®2645	Wapsee Valley Dent
- Date	May 3/90	May 5/90	May 7/90	May 31/90	May 28/90
- Rate (seeds/ha)	67,950	68,450	Not given	55,000	13 kg/ha
- Straw management	Chopped & spread	Chopped	Chopped & spread	Not given	Spread
- Primary tillage (1989)	None	Not given	Not given	Moldboard plough	None
- Secondary tillage (1990)	Not given	Not given	Not given	Cultivate (2X)	Disc & cultivate (1X)
- Postemerge tillage(1990)	Interrow cultivate (2X)	Interrow cultivate (2X)	Interrow cultivate (2X)	Interrow cultivate (2X)	Interrow cultivate (2X)
Fertilizer (1990)					
- Pre plant	140 kg/ha 0-0-60		Not given	Liquid hog manure	Composted manure
- At plant	112 kg/ha 5-26-23; 200 kg/ha 28-0-0	56 l/ha 6-24-6; 78 kg/ha Urea; 78 kg/ha Potash	Not given	None	None
- Post plant	140 kg/ha 32-0-0	340 l/ha 28-0-0	Not given	None	None
Pesticides (1990)					
- Pre plant	0.7 l/ha 2,4-Dester	None	None	None	None
- At plant	2.0 l/ha Dual®(12"band)	Dual® & Banvel® (10"band)	0.3 l/ha Bladex® (15"band)	None	None
- Post plant	1.0 l/ha 2,4-Dester (12"band)	Pardner®	Atrazine, Dual® (15"band)	None	None
Cover Crop Information					
Date of Application	June 27/90	July 2/90	June 30/90	July 24/90	July 17/90
1991 Cropping Information					
Crop	Soybeans	Soybeans	Soybeans	Soybeans	Soybeans
Variety	NK®S-20-20	Asgrow® 1895	Jacques®	Bin run	Bicentennial
Date	May 23/91	May 30/91	May 18/91	May 23/91	May 29/91
Rate (seeds/ha)	516,650	447,950	444,600	516,680	385,560
Primary tillage (1990)	None	None	None	None	None
Secondary tillage (1991)	None	None	Cultivate (2X)	Disc	Disc(2X)cultivate(1X) harrow(2X)
Post emerge tillage (1991)	Interrow cultivate (2X)	Interrow cultivate (1X)	Interrow cultivate (2X)	Interrow cultivate	Interrow cultivate (2X)
Planting Equipment					
- Planter/Drill	John Deere®7000	John Deere® 4 Row	I.H.® Air Planter	Plate Planter	I.H.® 4 Row Planter
- Attachments	2-2" wavy coulters/row	2 coulters + trash whippers/row	Yetter® coulters	None	None
Fertilizer (1991)					
- Pre plant	None	None	None	None	Composted manure
- At plant	None	28 l/ha 6-24-6	165 kg/ha 4-20-37	None	None
- Post plant	None	None	None	None	None
Pesticides (1991)					
- Pre plant	0.4 kg/ha Lexone (DF75)®	2.5 l/ha Roundup®	1.2 l/ha Rival®	None	None
- At plant	1.7 l/ha Lasso® (12"band)	Dual® Lexone® (10" band)	3.7 l/ha Patoran® (15"band)	None	None
- Post plant	1.5 kg/ha Lorox (DF50)® (12"band)			None	None

Table 3.3.3: Farm Management Practices for the Field Scale Barley, Oats and Annual Ryegrass Management System Projects, Barley Treatment Sites. Cover Crop Studies I and II, 1990-1991.

Farm Management Practices	Site 1	Site 2	Site 3
Previous Cropping Information (1990)			
- Crop	Corn	Barley	Winter Wheat
- Variety	Pioneer®3737	Leger	Frankenmuth
- Straw management	Not given	Baled	Chopped & spread
Cover Crop Information			
- Date of application (1990)	September 12/91	September 11/91	September 6/91
Tillage Practices			
- Primary (1990)	Moldboard plough	Moldboard plough	Moldboard plough
- Secondary (1991)	Cultivate	Cultivate	Cultivate
- Post emerge (1991)	None	None	None
Current Cropping Information (1991)			
- Crop	Soybeans	Soybeans	Soybeans
- Variety	NK® S-20-20	Maple Donavon	Pioneer®9061
- Date	May 27/91	June 4/91	May 26/91
- Rate (seeds/ha)	95 kg/ha	655,740	444,600
- Planting equipment	John Deere®7000 Max	Grain Drill	John Deere®750 No-Till
- Attachments	Emerge Planter	Packers	Grain Drill
Fertilizer (1991)			
- Pre plant	None	95 kg/ha 8-30-15	None
- At plant	112 kg/ha 5-24-32	None	34 l/ha 6-24-6
- Post plant	None	None	None
Pesticides (1991)			
- Pre plant	Dual®	None	Roundup®-spot treatment
- At plant	None	None	.05 l/ha Pursuit®
- Post plant	Lorox®	Pursuit®	2.5 l/ha Linuron 480®

Table 3.3.4: Farm Management Practices for the Field Scale Barley, Oats and Annual Ryegrass Management System Project, Oat Treatment Sites. Cover Crop Studies I and II, 1990-1991.

Farm Management Practices	Site 1	Site 2	Site 3
Previous Cropping Information (1990)			
- Crop	Barley	Winter Wheat	Barley
- Variety	Bin-run	Not given	Rodeo
- Straw management	Not given	Baled	Chopped and spread
Cover Crop Information			
- Date of application (1990)	September 5/91	September 13/91	September 9/91
Tillage Practices			
- Primary (1990)	Moldboard plough	Chisel plough	Mulch finisher (work in manure)
- Secondary (1991)	Cultivate	Cultivate (2X)	Mulch finisher
- Post emerge (1991)	Interrow cultivate	Interrow cultivate (1X)	None
Current Cropping Information (1991)			
- Crop	Soybeans	Soybeans	Soybeans
- Variety	Not given	Asgrow®1937	KG®-60
- Date	May 27/91	May 22/91	May 29/91
- Rate (seeds/ha)	516,680	450,900	583,600
- Planting equipment	John Deere®Plateless	John Deere®4-Row Planter	I.H.® 510 Drill
- Attachments	Planter	2 coulters & trash whippers per row	Press wheels
Fertilizer (1991)			
- Pre plant	None	None	20,200 l/ha hog manure (summer 1990)
- At plant	None	28 l/ha 6-24-6	
- Post plant	None	None	
Pesticides (1991)			
- Pre plant	None	None	Roundup® +
- At plant	None	Dual® + Lexone® (10"band)	Pursuit® None
- Post plant	None	Poast®	None

Table 3.3.5: Farm Management Practices for the Field Scale Barley Oats and Annual Ryegrass Management Systems Projects, Annual Ryegrass Treatment Sites. Cover Crop Studies I and II, 1990-1991.

Farm Management Practices	Site 1	Site 2	Site 3
Previous Cropping Information (1990)			
- Crop	Ryegrass	Mixed grain	Nato Beans
- Variety	Not given	Kippen, Leger, Neuman	Not given
- Straw management	Spread	Baled	Not given
Cover Crop Information			
- Date of application (1990)	June 19/91	June 25/91	June 17/91
Tillage Practices			
- Primary (1990)	Moldboard plough	Moldboard plough	None
- Secondary (1991)	Cultivate (2X)	Cultivate + harrow (3X)	None
- Post emerge (1991)	None	Interrow cultivate (2X)	Interrow cultivate (1X)
Current Cropping Information (1991)			
- Crop	Corn	Corn	Corn
- Variety	Pioneer®3790	Hyland®2003	Pioneer®3790
- Date	May 5/91	May 20/91	May 4/91
- Rate (seeds/ha)	69,160	65,950	70,400
- Planting equipment	I.H.®800 Air Planter	I.H.®56 - 4 Row Plate Planter	John Deere®7000
- Attachments			2-2" wavy coulters/row
Fertilizer (1991)			
- Pre plant	None	None	None
- At plant	68 kg/ha 6-25-30	112 kg/ha actual N(28%)	157 kg/ha 5-27-18 + 56 kg/ha actual N (28%)
- Post plant	59 kg/ha actual N	None	78 kg/ha actual N
Pesticides (1991)			
- Pre plant	None	None	None
- At plant	None	Dyfonate® + Lorsban Plus®	2.0 l/ha Dual® (12" band)
- Post plant	1.7 l/ha Dual® 0.6 l/ha Banvel®	Bladex® + Atrex® Basagran® + Assist®	1.2 l/ha Pardner® (12" band)

3.4 Measurements

i) Cover Crop Seeding Rate

One method of tracking the amount of cover crop seed applied to the treatments involved subtracting the amount of seed remaining after application from the initial seed weight. For the majority of the barley, oats and annual ryegrass management system sites a second method for measuring the amount of cover crop seed applied was also employed in 1991. At eight of the nine sites three replications of MacTac® placed on boards were laid across the width of the treatment strip (except for where the tractor drove). The stickiness of the MacTac® allowed the seeds to stick to these catchers. Once the seed had been applied the number of seeds that landed on the MacTac® catchers were counted and presented as the number of seeds per square metre.

i) Soil Residue Cover

A rope with knots at 15 cm intervals was used to make four counts of residue cover per treatment strip. Residue cover was determined by counting each knot on the rope that touched a piece of residue (previous crop and cover crop residue). These data were taken in late fall on all sites for all projects. In early spring, after runoff and after planting residue levels were measured on all treatments at each site involved in either the soybean-spring cereal cover crop-corn or corn-spring cereal and annual ryegrass cover crop-soybean management system projects. Data were adjusted to percent residue cover.

ii) Cover Crop Emergence

The number of cover crop seedlings (annual ryegrass or barley) emerged per square metre were counted at four separate locations within each treatment strip. These data were collected approximately three weeks after planting at each of the corn-spring cereal and annual ryegrass cover crop-soybean management system sites.

iii) Weed Counts

The number of weeds per square metre were counted by species at four separate locations within each treatment strip. These data were collected prior to corn harvest (1990) and late April (1991) before any tillage or chemical practices occurred at the sites involved in the corn-spring cereal and annual ryegrass cover crop-soybean management system project. The data at the barley, oats and annual ryegrass management system project sites were collected

concurrently with biomass accumulation in 1991.

iv) Cover Crop Biomass Accumulation

Live cover crop plants (annual ryegrass, barley or oats) from four 1.0 m^2 quadrats per treatment were clipped at ground level, placed in separate bags and frozen. These data were taken in late fall at all sites involved in the barley, oats and annual ryegrass management systems project. The samples were subsequently dried to a constant weight in a forced-air dryer. The dried weight values were adjusted to kilograms per hectare.

v) Crop Yield and Associated Factors

A combine, operated by the cooperator was employed to harvest the field crop within each treatment strip. The amount of seed obtained from each treatment was measured using a weigh wagon, with a sample of seed from each treatment being tested for moisture content at a local elevator.

The length of field harvested was measured and multiplied by the number of rows combined to give the total area harvested per treatment. The final seed yield per sample was adjusted to standard moisture (15.5% for corn and 14.0% for soybeans) and presented as megagrams (Mg) per hectare.

Yields were taken for corn in 1990 and soybeans in 1991 at the corn-spring cereal and annual ryegrass cover crop-soybean management system project sites. Corn yield data were collected in 1991 for the soybean-spring cereal cover crop-corn management system project sites as well as at the annual ryegrass sites from the barley, oats and annual ryegrass management systems project. No yield data were collected at the remaining sites.

vi) Rainfall Simulation

Rainfall simulation work was carried out by Ecological Services for Planning Limited (ESP) shortly after planting the main crop in 1991 at three sites. One site from the soybean-spring cereal cover crop-corn management system project compared the barley treatment to the control area while two sites from the corn-spring cereal and annual ryegrass cover crop-soybean management system project compared the annual ryegrass treatment to the control.

The area of the rainfall simulation was $1m^2$ and was replicated four times within each of the treatment strips. The rate of rainfall was 155 mm/hr which was run for either 10 (25.8 l of water/m^2) or 15 (38.7 l of water/m^2) minutes depending on the conditions of the site. Data collected included slope, residue cover, soil moisture, runoff volume, soil loss and sediment and soluble ortho phosphorus.

4.0 RESULTS

4.1 Cover Crop Seeding Rates

Variability in cover crop seeding rates occurred at most sites even though numerous calibrations were undertaken prior to seed application. A summation of the expected and actual rates of application for each of the projects is given in Table 4.1.1. These values are based on the initial amount of seed minus the amount of seed remaining after cover crop application.

In 1990 the oats seeding rate at the 10% soybean leaf drop sites was applied 30 to 100 kg/ha above the expected rate while the barley seeding rate was between 3 and 37 kg/ha above the target level . At the soybean harvest sites the barley var. Kippen application rate ranged from 4 kg/ha below to 65 kg/ha above the expected rate of 215 kg/ha. The seeding rate of the Leger barley for these same sites was 18 kg/ha above the target level while at the Chapais barley measured 36 kg/ha below the expected rate.

For the corn-spring cereal and annual ryegrass cover crop-soybean management system project site 4 recorded the most variable seeding rates. At this site the annual ryegrass was seeded 3.4 times above the targeted rate while the Rodeo and Leger barley were applied 1.6 and 0.8 times the expected rate, respectively. At the remaining sites the annual ryegrass seeding rate averaged 20 kg/ha which was 5 kg/ha above the recommended rate. With the exception of site 2 the remainder of the sites applied the barley varieties below the expected rate of 164 kg/ha. The average seeding rate for the barley treatments at site 1, 2, 3, and 5 was 91.5, 173.5, 123, and 136 kg/ha, respectively.

A second method of monitoring the amount of seed applied to the treatments was utilized in the barley, oats and annual ryegrass management system in 1991. The results of this 'MacTac® seed catching' method are illustrated in Figure 1. When both methods of monitoring seed application rates are compared it is evident that the amount of seed weighed in the first method is not always related to the number of seeds counted in the second method.

Table 4.1.1: Expected and Actual Application Rates of the Various Cover Crops Involved in the Cover Crop Studies I and II, 1990-1991.

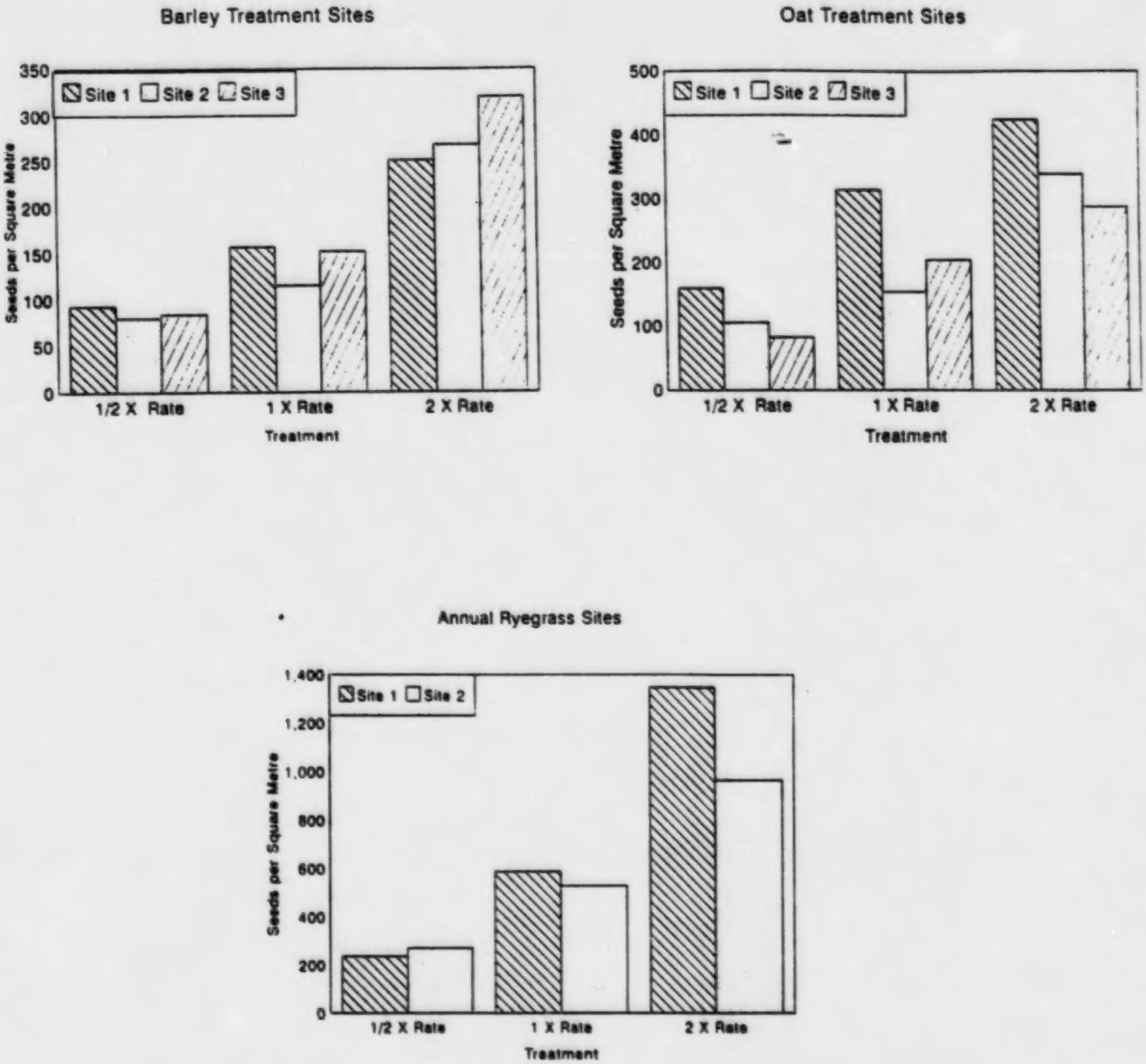
Project: Soybean-Spring Cereal Cover Crop-Corn Management Systems				
Soybeans at 10% Leaf Drop Sites				
Treatment	Expected Rate	Site 1	Site 2	Site 3
Oats var. Ogle	152 kg/ha	182 kg/ha	252 kg/ha	190 kg/ha
Barley var. Leger	215 kg/ha	218 kg/ha	233 kg/ha	252 kg/ha
Soybean Harvest Sites				
Treatment	Expected Rate		Site 4	Site 5
Barley var. Kippen	215 kg/ha		211 kg/ha	280 kg/ha
Barley var. Leger	215 kg/ha		233 kg/ha	Not applied
Barley var. Chapais	215 kg/ha		Not applied	179 kg/ha

Project: Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System						
Treatment	Expected Rate	Site 1	Site 2	Site 3	Site 4	Site 5
Annual Ryegrass	15 kg/ha	20 kg/ha	12 kg/ha	26 kg/ha	51 kg/ha	23 kg/ha
Barley var. Rodeo	164 kg/ha	92 kg/ha	169 kg/ha	118 kg/ha	262 kg/ha	140 kg/ha
Barley var. Leger	164 kg/ha	91 kg/ha	178 kg/ha	128 kg/ha	125 kg/ha	132 kg/ha

Project: Barley, Oats and Annual Ryegrass Management Systems				
	Barley Treatment Sites			
Treatment	Expected Rate	Site 1	Site 2	Site 3
½X	82 kg/ha	108 kg/ha (0.6X)*	100 kg/ha (0.6X)	94 kg/ha (0.6X)
1X	164 kg/ha	194 kg/ha (1.2X)	193 kg/ha (1.2X)	152 kg/ha (0.9X)
2X	328 kg/ha	346 kg/ha (2.1X)	259 kg/ha (1.6X)	301 kg/ha (1.8X)
	Oat Treatment Sites			
Treatment	Expected Rate	Site 1	Site 2	Site 3
½X	76 kg/ha	118 kg/ha (0.8X)	94 kg/ha (0.6X)	102 kg/ha (0.7X)
1X	152 kg/ha	199 kg/ha (1.3X)	152 kg/ha (1.0X)	208 kg/ha (1.4X)
2X	304 kg/ha	345 kg/ha (2.3X)	311 kg/ha (2.0X)	360 kg/ha (2.4X)
	Annual Ryegrass Treatment Sites			
Treatment	Expected Rate	Site 1	Site 2	Site 3
½X	7.5 kg/ha	11 kg/ha (0.7X)	8 kg/ha (0.5X)	15 kg/ha (1.0X)
1X	15 kg/ha	18 kg/ha (1.2X)	16 kg/ha (1.1X)	21 kg/ha (1.4X)
2X	30 kg/ha	59 kg/ha (3.9X)	29 kg/ha (1.9X)	37 kg/ha (2.5X)

* Values in brackets are the actual seeding rate treatments.

Figure 1: **The Number of Seeds Counted From the Barley, Oats and Annual Ryegrass Management Project Sites Using the 'MacTac® Seed Catching' Method.**



At the barley treatment sites all the 1/2X treatments were actually applied at the 0.6X seeding rate with Figure 1 showing a similar number of seeds per square metre. Greater variability was reported in the 1X treatment with sites 1 and 2 both recording an application rate of 1.2X but showed a difference of 50 seeds/m^2. Also at this 1X treatment site 3 (actual rate = 0.9X) reported approximately 155 seeds/m^2 which was intermediate of the number of seeds reported at sites 1 and 2. In the 2X treatment site 1 recorded the highest actual seeding rate at 2.1X but measured the least number of barley seeds/m^2 as shown in Figure 1. Of the oat treatment sites, site 2 recorded the closest to expected seeding rates (Table 4.1.1). When comparing the two methods of monitoring seed application rates site 3 measured fewer oat seeds/m^2 than the value indicated in Table 4.1.1.

Two of the three annual ryegrass sites utilized the second method of monitoring seed application rates. At site 2 the annual ryegrass was applied at the target rate for the 1/2X rate treatment, however the number of seeds counted per square metre was slightly above that recorded at site 1 which applied this treatment at 0.7X. For the 1X treatment similar levels of seed application rates at sites 1 and 2 were reported in both Table 4.1.1 and Figure 1. Even though there was a difference of two times the seeding rate recorded by the first method between sites 1 and 2 for the 2X treatment the second method of monitoring did not illustrate this variability in the data (Figure 1).

4.2 Soil Surface Residue Cover

Tables 4.2.1 through 4.2.7 summarize the mean residue levels attained for each of the sites involved in the cover crop study projects.

Table 4.2.1 illustrates the residue level results taken after soybean harvest on the "soybean at 10% leaf drop" and "at soybean harvest" treatments of the soybean-spring cereal cover crop-corn management system sites. It is apparent that the oat treatment applied at 10% leaf drop resulted in higher residue levels at all three sites. While the barley treatments measured higher residue levels at two of the three sites when compared to the control. When examining the combined data for all sites, both barley and oats treatments generated significantly higher levels of residue after harvest. Although these differences were found to be statistically significant, in reality a difference of 5% may not be seen as significant.

With regard to the after harvest residue levels reported at the sites involved in the application of the spring cereals at soybean harvest there was no advantage to applying any of the cover crop treatments.

In general, the annual ryegrass treatment provided significantly more residue after harvest than either of the barley treatments when compared to the control at the corn-spring cereal and annual ryegrass cover crop-soybean management system sites (Table 4.2.2). At site 1 interrow cultivation followed by broadcasting the annual ryegrass seed attained a slightly higher residue level than seed broadcast followed by cultivation treatment and was significantly higher than the control. No significant differences between treatments and the control were measured at site 2. The annual ryegrass treatments reported a significant increase in residue cover of approximately 4% and 30% at sites 3 and 5 respectively when compared to their control areas. At site 4 the annual ryegrass and Leger barley treatments produced significantly greater residue levels than the control. When the data were combined for sites 1, 2 and 3 (all band sprayed) this difference only held for the annual ryegrass treatment.

Sites 4 and 5 (organically managed farms) combined data indicate that both the annual ryegrass and Leger barley treatments were significantly higher than the control. The analysis of the overall data (sites 1 to 5 combined) recorded results similar to that of sites 4 and 5.

Following spring runoff none of the treatments at any of the sites involved in the soybean-spring cereal cover crop-corn management system project provided significantly more residue than the control except for site 3 (Table 4.2.3). At site 3, the oat treatment residue level was significantly higher than that of the control. The combined data from sites 1, 2 and 3 showed that the oat treatment resulted in significantly more residue (+6%) than the control whereas the barley treatments measured slightly lower residue levels. The use of Kippen barley as a cover crop applied to soybeans at harvest was not advantageous after spring runoff when the data from sites 4 and 5 were combined.

From the information shown in Table 4.2.4 the annual ryegrass treatment resulted in significantly higher residue levels after spring runoff than the control at three of the five corn-spring cereal and annual ryegrass cover crop-soybean management system project sites (sites 1, 2 and 5). At the two remaining sites there was no significant difference between

Table 4.2.1: Results of the After Harvest Soil Surface Residue Levels for the Soybean-Spring Cereal Cover Crop-Corn Management System Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean After Harvest Soil Residue Levels (1990) (%)			T-test Results*	
	Soybeans at 10% Leaf Drop				
	Oats	Barley	Control	Oats	Barley
Site 1	98	96	93	Yes	Yes
Site 2	93	93	88	Yes	Yes
Site 3	97	96	92	Yes	No
Mean of Sites 1, 2 & 3	96	95	91	Yes	Yes

	Soybeans at Harvest				
	Kippen Barley	Leger Barley	Chapais Barley	Control	Kippen Barley
Site 4	96	96	-	96	No
Site 5	95	-	90	93	No
Mean of Sites 4 & 5	96	96	90	95	No

* Yes = significant, no = no significant differences between treatment and control areas ($P \leq 0.05$).

Table 4.2.2: Results of the After Harvest Soil Surface Residue Levels for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean After Harvest Soil Residue Levels (1990)(%)				T-test Results*		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	99	96	96	95	No	No	No
C/S**	100	96	96		Yes	No	No
Site 2	96	94	94	96	No	No	No
Site 3	99	93	97	95	Yes	No	No
Site 4	99	89	93	79	Yes	No	Yes
Site 5	94	68	67	64	Yes	No	No
Mean of Sites 1, 2 & 3†	98	95	96	96	Yes	No	No
Mean of Sites 4 & 5‡	96	78	80	72	Yes	No	Yes
Mean of All Sites	98	89	90	86	Yes	No	Yes

* Yes = significant, no = no significant differences between treatment and control areas ($P \leq 0.05$).

** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.

† Herbicides applied in bands at these sites.

‡ Organically managed farms.

Table 4.2.3: Results of the after Spring Runoff Soil Surface Residue Levels for the Soybean-Spring Cereal Cover Crop-Corn Management Systems Project. Cover Crop Studies 1 and II, 1990-1991

Site	Mean After Spring Runoff Soil Residue Levels (1991) (%)			T-test Results*	
Soybean at 10% Leaf Drop Site					
	Oats	Barley	Control	Oats	Barley
Site 1	87	85	83	No	No
Site 2	70	54	56	No	No
Site 3	93	88	91	Yes	No
Mean of Sites 1, 2 & 3	83	76	77	Yes	No

	Soybean Harvest Sites				
	Kippen Barley	Leger Barley	Chapais Barley	Control	Kippen Barley
Site 4	85	86	-	88	No
Site 5	83		87	80	No
Mean of Sites 4 & 5	84	86	87	84	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).

Table 4.2.4: Results of the After Spring Runoff Soil Surface Residue Levels for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project. Cover Crop Studies I and II, 1990-1991.

	Mean After Spring Runoff Residue Levels (1991)(%)				T-test Results*		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	98	94	96	93	Yes	No	Yes
C/S**	98	96	98		Yes	No	Yes
Site 2	92	91	83	88	Yes	No	No
Site 3	95	88	87	88	No	No	No
Site 4	60	36	37	36	No	No	No
Site 5	83	70	67	64	Yes	No	No
Mean of Sites 1, 2 & 3†	96	92	91	90	Yes	No	No
Mean of Sites 4 & 5‡	71	53	52	50	Yes	No	No
Mean of All Sites	88	79	78	74	Yes	No	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).

** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.

† Herbicides applied in bands at these sites.

‡ Organically managed farms.

the treatment and control areas. In addition, the Leger barley treatment at site 1 under both seeding conditions also measured significantly higher residues than the control. The combined data for sites 1, 2 and 3, as well as sites 4 and 5 report an increase of 6% and 21%, respectively for the annual ryegrass treatments over the control. The combined data for all five sites resulted in a mean increase in residue of 14% for the annual ryegrass.

Neither the oat nor barley treatments had a significant effect on residue levels after planting for the soybean-spring cereal cover crop-corn management system project sites (Table 4.2.5).

With the exception of the Leger barley treatment at sites 3 and 5, none of the treatments measured more residue than the control areas after planting in the corn-spring cereal and annual ryegrass cover crop-soybean management system project as shown in Table 4.2.6. The Leger barley treatment at sites 3 and 5 was found to have significantly higher residue (+9% and +2% respectively) than the control. Under no-tillage conditions the overall residue level after planting was approximately 58% at sites 1 and 2. When secondary tillage practices (e.g. disk, cultivate) were carried out prior to planting by the organic type cooperators the residue remaining after planting in the annual ryegrass treatment ranged from 13% to 14% while the remaining treatments ranged from 7% to 10%. These differences in residue level were insignificant when compared to the control. The analyses summarized over all sites indicated that the annual ryegrass treatment had a significant effect on the after planting residue levels.

The results for the after soybean harvest residue levels for the barley, oats and annual ryegrass management system project sites show that at the sites which contained the barley seeding rates only one site had a treatment that was significantly different from the control (Table 4.2.7). At site 2 the 2X seeding rate treatment reported a 5% higher residue level than the control area. When the residue levels were averaged over all the barley sites each of the seeding rate treatments resulted in significantly higher after harvest residue levels than the control treatment. These data indicate that seeding barley into soybeans at 10% leaf drop at any of the rates (1/2X, 1X or 2X) had a positive effect on after harvest residue level.

Results indicate that only two of the oat treatments, one each at two different sites, were significantly different than the control. The 1X oat seeding rate treatment at site 2 recorded

a significantly higher residue level than the control (+8%). Even though the 2X seeding rate treatment at this site averaged slightly higher residue levels than the 1X seeding rate treatment the variability of these data resulted in an insignificant residue level difference from the control. Only the 2X seeding rate treatment produced significantly more residue than the control strip at site 3 with an approximate 8% increase in residue levels. From the combined data, only the 1X seeding rate treatment displayed significantly higher residue levels than the control plots. Overall, there was no advantage to increasing the oat seeding rate to 2X as the 1X seeding rate was found to provide significantly higher residue levels after harvest.

Due to the poor germination and growth of the annual ryegrass in 1991, the after harvest residue levels from the three seeding rate treatments were found to be insignificant when compared to the control area. These results were observed for the individual sites as well as from the combined data. Therefore, in 1991 there was no advantage to applying annual ryegrass into corn with regard to increasing after harvest residue levels at these sites.

Table 4.2.5: Results of the After Planting Soil Surface Residue Levels for the Soybean-Spring Cereal Cover Crop-Corn Management Systems Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean After Planting Soil Residue Levels (1991) (%)			T-test Results*	
Soybean at 10% Leaf Drop Sites					
	Oats	Barley	Control	Oats	Barley
Site 1	67	64	61	No	No
Site 2	3	9	4	No	No
Site 3	37	20	19	No	No
Mean of Sites 1, 2 & 3	35	31	28	No	No
Soybean Harvest Sites					
	Kippen Barley	Leger Barley	Chapais Barley	Control	Kippen Barley
Site 4	48	39	-	44	No
Site 5	25		27	24	No
Mean of Sites 4 & 5	37	39	27	34	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).

Table 4.2.6: Results of the After Planting Soil Surface Residue Levels for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management Systems Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean After Planting Residue Levels (1991)(%).				T-test Results*		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	54	57	51	54	No	No	No
C/S**	59	54	49		No	No	No
Site 2	75	63	61	54	No	No	No
Site 3	25	27	33	24	No	No	Yes
Site 4	14	9	9	10	No	No	No
Site 5	13	7	10	8	No	No	Yes
Mean of Sites 1, 2 & 3†	53	50	49	44	Yes	No	No
Mean of Sites 4 & 5‡	14	8	10	9	Yes	No	No
Mean of all Sites	40	36	36	30	Yes	Yes	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).
** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.
† Herbicides applied in bands at these sites.
‡ Organically managed farms.ryegrass cover crop-soybean management system project sites (sites 1, 2 and

Table 4.2.7 Results of the After Harvest Soil Surface Residue Levels for the Barley, Oats and Annual Ryegrass Management System Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean After Harvest Soil Residue Level (1991)(%)				T-test Results*		
	1/2X	1X	2X	Control	1/2X	1X	2X
Barley Sites							
Site 1	93 (0.6X)†	95 (1.2X)	96 (2.1X)	88	No	No	No
Site 2	91 (0.6X)	90 (1.2X)	91 (1.6X)	86	No	No	Yes
Site 3	70 (0.6X)	83 (0.9X)	76 (1.8X)	64	No	No	No
Mean of All Barley Sites	84 (0.6X)	89 (1.1X)	88 (1.8X)	79	Yes	Yes	Yes
Oat Sites							
Site 1	77 (0.8X)	83 (1.3X)	65 (2.3X)	70	No	No	No
Site 2	71 (0.6X)	73 (1.0X)	79 (2.0X)	65	No	Yes	No
Site 3	87 (0.7X)	86 (1.4X)	94 (2.4X)	86	No	No	Yes
Mean of All Oat Sites	78 (0.7X)	81 (1.2X)	79 (2.2X)	73	No	Yes	No
Annual Ryegrass Sites**							
Site 1	88 (0.7X)	91 (1.2X)	91 (3.9X)	88	No	No	No
Site 3	95 (1.0X)	97 (1.4X)	95 (2.5X)	97	No	No	No
Mean of All Annual Ryegrass Sites	91 (0.9X)	94 (1.3X)	93 (3.2X)	92	No	No	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).
† Values in brackets are the actual seeding rate treatments.
** Data from site 2 not collected. See Section 2.0 for details.

4.3 Cover Crop Plant Emergence

In general, the number of cover crop plants emerged at the corn-spring cereal and annual ryegrass cover crop-soybean management system project sites can be related to the relative amount of seed applied at each site. An example of this is site 5 which had an extremely high application rate of annual ryegrass and Rodeo barley seed which resulted in the highest emergence count in these two treatments.

The annual ryegrass application rate at site 3 was approximately 1.7 times higher than the expected rates whereas the barley application rate was only 0.75 times the expected rate. This was reflected in the number of cover crop plants emerged. In fact, when the annual ryegrass was compared to either of the barley treatments, it resulted in significantly higher plant emergence (Table 4.3.1). Even though the difference in seedling emergence may be larger for some of the other sites, the variability in the data resulted in non-significant differences.

Emergence of the annual ryegrass was decreased by half as a result of one interrow cultivator pass over the plot after broadcasting the seed compared to cultivating then seeding (site 1, Table 4.3.1). The opposite occurred in the barley plots with an increase in seedling emergence when the seeds had been slightly covered with soil by the cultivator. In comparing the three treatments to each other the t-test results indicated that there were no significant differences in seedling emergence at this site (site 1) or at sites 2, 4 or 5.

The analysis of the mean seedling emergence for the combined data from sites 1, 2 and 3 and over all sites indicated that the annual ryegrass treatment measured significantly more seedlings per square metre than either of the barley treatments. This stands to reason as the number of seeds applied per unit area would be greater for annual ryegrass than barley because of the seed size.

Table 4.3.1: Results of the Cover Crop Plant Emergence Levels for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean Cover Crop Plants Emerged (#/m^2)			T-test Results*		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Annual Ryegrass vs. Rodeo	Rodeo vs. Leger	Leger vs. Annual Ryegrass
Site 1 S/C**	146	175	152	No	No	No
C/S**	368	91	120	No	No	No
Site 2	273	243	282	No	No	No
Site 3	337	154	147	Yes	No	Yes
Site 4	934	584	289	No	No	No
Site 5	451	327	409	No	No	No
Mean of Sites 1, 2 & 3†	281	166	175	Yes	No	Yes
Mean of Sites 4 & 5‡	693	456	349	No	No	No
Mean of all Sites	418	263	233	Yes	No	Yes

* Yes = significant, no = no significant differences between treatment and control areas ($P \leq 0.05$).

** S/C=Cover crop seeded prior to interrow cultivation; C/S =Interrow cultivation followed by cover crop seeding.

† Herbicides were applied in bands at these sites.

‡ Organically managed farms.

4.4 Weed Counts

Project: Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System

General comparisons between the weed counts taken in the fall and spring can only be made as the location of the measurements varied between dates within each treatment strip. It is also important to bear in mind that the spring data were collected prior to tillage or chemical application. A summary of the number of weeds counted or a rating are given for each site along with a listing of the most prevalent weed(s) in Table 4.4.1. Even though the annual ryegrass is considered an annual, vigorous growth was reported in each site the following spring (1991).

Table 4.4.1: Weed Count Data Collected in the Fall (1990) and Spring (1991) for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project Sites. Cover Crop Studies I and II, 1990-1991.

	Site 1-S/C†		Site 1-C/S†		Site 2		Site 3		Site 4		Site 5	
Treatment	Total #/m²	Most Prevalent Weed(s)	Total #/m²	Most Prevalent Weed(s)	Total #/m²	Most Prevalent Weed(s)	Total #/m²	Most Prevalent Weed(s)	Total #/m²	Most Prevalent Weed(s)	Total #/m²	Most Prevalent Weed(s)
Annual Ryegrass - fall (1990)	84	Pigweed Chickweed	106	Pigweed Chickweed	1		4		2		61	Plantain
- spring (1991)	E*	Pigweed Chickweed	106	Chickweed Pigweed	15				16	Mustard Wild Buckwheat	30	Plantain
	H*	Annual ryegrass escapes	H*	Annual ryegrass escapes	H*	Annual ryegrass escapes	H*	Annual ryegrass escapes	H*	Annual ryegrass escapes	H*	Annual ryegrass escapes
Rodeo Barley - fall (1990)	70	Pigweed	53	Pigweed Chickweed	0		18	Pigweed	3		86	Plantain
- spring (1991)	111	Chickweed Dandelion	108	Chickweed Dandelion Pigweed	0		8	Quackgrass	32	Wild Buckwheat Mustard Ragweed Quackgrass	65	Plantain
Leger Barley - fall (1990)	41	Pigweed	27	Pigweed Chickweed	1		13	Pigweed	2		82	Plantain
- spring (1991)	9	Dandelion	7	Dandelion	0		6	Quackgrass	16	Mustard Ragweed Grasses	23	Plantain Foxtail
Control - fall (1990)	49	Pigweed Chickweed Nightshade	49	Pigweed Chickweed Nightshade	1		18	Pigweed	6	Dandelion	105	Plantain
- spring (1991)	44	Pigweed Chickweed Dandelion	44	Pigweed Chickweed Dandelion	1		3	Quackgrass	19	Wild Buckwheat Mustard Ragweed	81	Plantain Yarrow
Overall Weed Pressure*		Excessive		Excessive		Light		Moderate - Heavy		Light-Heavy		Heavy

† S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.
* Rating System

# weeds/m²	Rating
0-1	Light (L)
2-9	Moderate (M)
10+	Heavy (H)
50+ or solid mat	Excessive (E)

At site 1 (which used herbicides applied in bands over the main crop row and interrow cultivation for weed control) pigweed and chickweed were the most prevalent weeds followed by dandelion and nightshade. The chickweed, in particular, was found in many patches (mats) across the field. In general, this field was rated as having excessive weed pressure in both the fall and spring which may affect the actual crop yield. The Leger barley treatment was the cleanest as a result of less chickweed pressure, however this treatment was still rated as having heavy to excessive weed pressure. The annual ryegrass treatment did not seem to decrease the weed pressure, in fact the highest number of weeds were found in this treatment. No consistent differences between application methods (S/C vs. C/S) were observed at this site.

Very few, if any weeds were observed at site 2 on any of the treatments even though this field was managed similar to site 1. The overall weed rating of this field was considered light.

The most frequently reported weed species in site 3 (again managed similar to site 1) were pigweed in the fall and quackgrass in the spring. The annual ryegrass treatment plot was found to have the least number of weeds in the fall while the control area had the least in the spring. Overall, the weed pressure was similar across all treatments which may signify that the treatments had little affect on weed numbers at this site.

The organic producer at site 4, who used tillage as the primary source for weed control, had mentioned that mustards were the major weed problem in his fields. Therefore it was expected that mustard would be observed while doing weed counts. In addition to mustard, some other prevalent weeds were wild buckwheat, ragweed and quackgrass (especially in the spring). In general the annual ryegrass and Leger barley treatments reported the least amount of weeds. However the difference in weed numbers among all treatments did not vary a great deal.

Plantain was the most outstanding weed at site 5. This site was organically managed therefore tillage was the primary source of weed control. An excessive number of weeds were observed in each of the treatments in the fall. By spring each of the cover crop treatments had reduced the number of weeds with the annual ryegrass and Leger barley treatments having the greatest effect. However, weed pressure was still at excessive levels in the spring for all treatments.

Weed counts taken in late fall at each of these sites were considerably lower compared to the above mentioned study. On average, one to three weeds were observed per square metre (data not shown). This difference in weed pressure may be related to or a combination of the following:

individual farm management practices (tillage and spray programs);
weather conditions throughout the season;
previous weed problems; and
previous and current crop.

4.5 Cover Crop Biomass Accumulation

Biomass accumulation samples were taken in late fall of the establishment year (1991) for the barley, oat and annual ryegrass management system project sites. Statistical differences were determined to see which of the various seeding rates provided significantly more dry matter. The results are presented in Table 4.5.1.

Even though the barley 1X treatment seeding rate at site 1 was 88 kg/ha more than the 1/2X treatment the biomass accumulation for these two treatments were not significantly different (Table 4.5.1). The biomass accumulation for the 2X treatment at this site was approximately 2.5 and 2.4 times greater than of 1/2X and 1X seeding rate treatments respectively. At site 2 of the barley treatment sites the 1/2X treatment was found to accumulate significantly lower amounts of biomass than both the 1X and 2X treatments. However no statistical difference was reported between the 1X and 2X treatments at this site. No differences in biomass accumulation were reported for site 3 of the barley sites even though the dry matters ranged from 110 to 400 kg/ha. This insignificant difference may again be attributed to the variability of the data. The analysis of the combined data from sites 1, 2 and 3 indicate that the average dry matter from the 2X treatment was significantly higher than either the 1/2 or 1X treatment.

The actual seeding rates for site 2 of the oat treatment sites were the lowest compared to sites 1 and 3 but resulted in the highest amount of accumulated biomass. These unexpected results may be related to temperature and precipitation in relation to spreading the cover crop as well as the stage of soybean leaf drop. As shown in Table 4.5.1 the 1X treatment

at site 1 produced only 45 kg/ha of oat dry matter which resulted in nonsignificant differences between this treatment and the 1/2X treatment. The 2X treatment produced significantly more dry matter than the 1/2X (+175 kg/ha) and 1X (+170 kg/ha) treatments at this site. The 1/2X treatment at sites 2 and 3 of the oat treatment sites were found to have produced significantly less biomass than either the 1X or 2X treatments. However no differences were reported between the 1X and 2X treatments. Statistical analysis of the combined data from the three oat sites report that each treatment accumulated significantly different amounts of biomass starting with the 1/2X treatment and increasing as the seeding rate increased.

Table 4.5.1: Results of the Cover Crop Biomass Accumulation for the Barley, Oats and Annual Ryegrass Management System Project. Cover Crop Studies 1 and II, 1990-1991.

Site	Mean Biomass Accumulation (kg Dry Matter/ha)			T-test Results*		
	1/2X	1X	2X	1/2X vs. 1X rate	1/2X vs. 2X rate	1X vs. 2X rate
Barley Treatment Sites						
Site 1	353 (0.6X)†	373 (1.2X)	893 (2.1X)	No	Yes	Yes
Site 2	80 (0.6X)	175 (1.2X)	260 (1.6X)	Yes	Yes	No
Site 3	110 (0.6X)	180 (0.9X)	400 (1.8X)	No	No	No
Mean of Sites 1, 2 & 3	181 (0.6X)	242 (1.1X)	518 (1.9X)	No	Yes	Yes
Oat Treatment Sites						
Site 1	40 (0.8X)	45 (1.3X)	215 (2.3X)	No	Yes	Yes
Site 2	205 (0.6X)	390 (1.0X)	630 (2.0X)	Yes	Yes	No
Site 3	50 (0.7X)	155 (1.4X)	335 (2.4X)	Yes	Yes	No
Mean of Sites 1, 2 & 3	98 (0.7X)	197 (1.2X)	393 (3.2X)	Yes	Yes	Yes
Annual Ryegrass Treatment Sites						
Site 1	50 (0.7X)	38 (1.2X)	200 (3.9X)	No	Yes	Yes
Site 2**	NA	NA	NA	NA	NA	NA
Site 3	38 (1.0X)	275 (1.4X)	295 (2.5X)	Yes	No	No
Mean of Sites 1 & 3	44 (0.9X)	157 (1.3X)	248 (2.2X)	No	Yes	No

† Values in brackets are the actual seeding rate treatments.
* Yes = significant, no = no significant differences between treatment and control areas ($P \leq 0.05$).
** No biomass accumulation data collected at this site. See Section 2.0 for details.

At the two sites where annual ryegrass biomass accumulation was collected, no general trend was apparent for any of the treatments. At site 1 the 1X treatment produced lower amounts of dry matter than the 1/2X treatment, however this difference was insignificant. The 2X treatment accumulated 400% and 526% more dry matter than the 1/2X or 1X treatment, respectively. This difference was found to be significant. On the other hand an insignificant difference of only 20 kg/ha of dry matter was reported between the 1X and 2X treatments at site 3. The analysis show that the 1/2X treatment dry matter was significantly different than the 1X treatment but not the 2X treatment. Again variation in the dry matters collected would account for these results. The combined data results indicate that only the dry matter from the 1/2X treatment was significantly different from the remaining treatments.

Due to the lack of precipitation at time of planting and the advanced growth stage of corn, the amount of annual ryegrass dry matter produced was observed to be below that of the annual ryegrass growth in the first year of the project.

4.6 Crop Yield and Associated Factors

4.6.1 Crop Yield

The combined data from the soybeans at 10% leaf drop sites showed no effect of spreading the cover crop into soybeans in 1990 on the corn yields in 1991 for the soybean-spring cereal cover crop-corn management systems project. These same results were found for the sites where the cover crop was broadcast into the soybean at harvest (Table 4.6.1.1).

The cover crop treatments at the corn-spring cereal and annual ryegrass cover crop-soybean management system project sites which had herbicide sprayed in bands (sites 1, 2 and 3) were found to be insignificant when compared to the control area yields in both the year of application (1990-corn) and the following year (1991-soybeans). The mean corn yield (Table 4.6.1.2, 1990) from the treatment and control plots from these sites reported a variation of only 2% between the highest and lowest yielding treatments.

Table 4.6.1.1: Results of the Corn Grain Yield Harvested in 1991 (Year Following Cover Crop Application) for the Soybean-Spring Cereal Cover Crop-Corn Management System Project Sites. Cover Crop Studies I and II, 1990-1991.

Site	Corn Grain Yield at 15.5% (Mg/ha)			Treatment Minus Control (Mg/ha)	
Soybeans at 10% Leaf Drop Sites					
	Oats	Barley	Control	Oats	Barley
Site 1	6.60	6.01	6.52	+0.08	-0.42
Site 2	7.39	7.71	7.21	+0.18	+0.50
Site 3	10.04	9.57	9.64	+0.40	-0.07
Mean of Sites 1, 2 & 3	8.01	7.76	7.79	+0.22*	-0.33*

Soybean Harvest Sites					
	Kippen Barley	Leger Barley	Chapais Barley	Control	Kippen Barley
Site 4	7.47		7.83	7.60	-0.13
Site 5	6.26	6.48		6.70	-0.44
Mean of Kippen Treatments	6.87			7.15	-0.28*

* Not significant according to a t-test at P≤0.05.

Table 4.6.1.2: Results of the Corn Grain Yield Harvested in 1990 (Year of Cover Crop Application) for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project Sites. Cover Crop Studies I and II, 1990-1991.

Site	Corn Grain Yields at 15.5% (Mg/ha)				Treatment Minus Control (Mg/ha)		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	8.15	8.11	8.10	8.01	+0.014	+0.10	+0.09
C/S**	7.94	8.28	7.93		-0.07	+0.27	-0.08
Site 2	8.90	8.64	9.37	9.07	-0.17	-0.43	+0.30
Site 3	8.21	8.24	8.25	8.23	-0.02	+0.01	+0.02+
Site 4	3.34	3.25	3.36	3.34	0	-0.09	+0.02
Site 5	2.11	2.22	2.08	2.91	-0.80	+0.69	-0.83
Mean of Sites 1, 2 & 3†	8.30	8.32	8.41	8.44	-0.14*	-0.12*	-0.03*
Mean of Sites 4 & 5‡	2.73	2.73	2.72	3.13	-0.40*	-0.40*	-0.41*
Mean of All Sites	6.44	6.46	6.52	6.31	+0.13*	+0.15*	+0.21*

* Not significant according to a t-test at P≤0.05.

** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.

† Herbicides applied in bands at these sites.

‡ Organically managed farms.

The corn yields measured from the organic type cooperator sites (sites 4 and 5) were considerably lower than the band sprayed sites. The mean control corn yields from sites 4 and 5 combined were approximately 15% higher than the annual ryegrass or either barley treatment. However, this difference was statistically insignificant.

When the data from all sites (sites 1 through 5) were combined, no significant differences were reported between the treatment and control areas. In general the control treatment was found to have produced the lowest corn yields (Table 4.6.1.2) while the Leger barley treatment reported the highest average yield. The difference in corn yields was only 3% between these two treatments. Therefore the effect of spreading the cover crops into corn did not significantly affect the corn yield or the subsequent soybean yield under either management practice (band spraying or organic).

The variation in soybean yields between the organic and band sprayed sites was not as evident as with corn. In fact site 4 produced the highest overall average soybean yields compared to the remaining sites. The statistical analysis indicate that soybeans grown the year following cover crop establishment were not affected in terms of the yield production. These results were consistent for each type of management practices (organic and band sprayed) as well as for the overall combined data (Table 4.6.1.3).

Yields were only harvested from the annual ryegrass sites of the barley, oats and annual ryegrass management system project. The results indicate that there was no effect on corn yield in 1991 from spreading annual ryegrass at various rates into the corn compared to the control area (Table 4.6.1.4). These results would be expected in this year as the growth of the annual ryegrass was minimal and would likely not have affected the growth of the corn plants.

Table 4.6.1.3: Results of the Soybean Seed Yield Harvested in 1991 (Year Following Cover Crop Application) for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project Sites. Cover Crop Studies I and II, 1990-1991.

Site	Soybean Seed Yields at 14.0% (Mg/ha)				Treatment Minus Control		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	3.15	3.14	3.09	3.15	0	-0.11	-0.06
C/S**	3.07	2.97	3.29		-0.08	-0.18	+0.14
Site 2	2.69	2.70	2.72	2.87	-0.18	-0.17	-0.15
Site 3	3.11	3.19	3.32	3.03	+0.08	+0.16	+0.29
Site 4	3.35	3.37	2.99	3.23	+0.12	+0.14	-0.24
Site 5	2.20	2.08	2.05	2.15	+0.05	-0.07	-0.10
Mean of Sites 1, 2 & 3†	3.01	3.00	3.11	3.02	-0.01*	-0.02*	+0.09*
Mean of Sites 4 & 5‡	2.78	2.73	2.52	2.69	+0.09*	+0.04*	+0.17*
Mean of All Sites	2.93	2.91	2.91	2.89	+0.04*	+0.02*	+0.02*

* Not significant according to a t-test at P≤0.05.

** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.

† Herbicides were applied in bands at each of these sites.

‡ Organically managed farms.

Table 4.6.1.4: Results of the Corn Grain Yield Harvested in 1991 (Year of Cover Crop Application) for the Barley, Oats and Annual Ryegrass Management System Projects, Annual Ryegrass Treatment Sites. Cover Crop Studies I and II, 1990-91.

Site	Corn Grain Yield at 15.5% (Mg/ha)				Treatment Minus Control (Mg/ha)		
	1/2X	1X	2X	Control	1/2X	1X	2X
Site 1	8.15 (0.7X)†	7.78 (1.2X)	7.64 (3.9X)	6.39	+1.76	+1.39	+1.25
Site 2	9.24 (0.5X)	9.00 (1.1X)	9.93 (1.9X)	10.33	-1.09	-1.33	-0.40
Site 3	8.98 (1.0X)	8.72 (1.4X)	8.75 (2.5X)	8.75	+.023	-0.03	0
Mean of All Sites	8.79 (0.7X)	8.50 (1.2X)	8.77 (2.8X)	8.49	+0.30*	+0.01*	+0.28*

* Not significant according to a t-test at P≤0.05.

† Values in brackets are the actual seeding rate treatments.

4.6.2 Moisture Content Of Seed At Harvest

A sample of the seed from each treatment strip was collected at harvest and the moisture content determined. These data are presented in Tables 4.6.2.1 to 4.6.2.4.
There were insignificant differences in grain corn moisture content among the treatments at the sites involved in the soybean-spring cereal cover crop-corn management system project. As shown in Table 4.6.2.1 less than a 1% difference was recorded for the grain corn moisture content at sites 1, 2 and 3 (combined data) while a difference of slightly over 1% was reported at sites 4 and 5.

Of the corn-spring cereal and annual ryegrass cover crop-soybean management system project sites the corn grain moisture content for the annual ryegrass treatment was found to produce, on average, significantly higher moisture contents than the control area when managed organically (Table 4.6.2.2). In contrast, the corn grown in the Leger barley treatment area measured a significantly lower grain corn moisture content than the control. However, when all sites were combined (sites 1 to 5) none of the cover crop treatments were found to vary significantly from the control areas. The soybean seed moisture content at harvest from the combined sites (Table 4.6.2.3) ranged from 13.4% to 13.8% with an average of 13.6%. As expected these differences were found to be insignificant.

Initially site 2 was planted as a silage corn crop. However the area where the annual ryegrass seeding rate trial was located was harvested as field corn. This can explain the differences in corn grain moisture content between this site and sites 1 and 3.

4.7 Rainfall Simulation

Rainfall simulation results as adapted from ESP are given in Table 4.7.1.

From the various data collected during the rainfall simulation work at the site involved in the soybean-spring cereal cover crop-corn management system project it was found that only the results from one parameter were significantly different from the control. In this case the soil moisture content of the control area increased by approximately 2% compared to the barley treatment area. Water runoff volumes for the control area measured 72% more than the barley treatment plots while soil loss increased by 82%. Similar levels of available phosphorus were detected from each of the samples, however considerably more sediment phosphorus (+5 mg/m^2) was reported in the control plots.

Table 4.6.2.1: Results of the Grain Corn Moisture Content at Harvest (Year Following Cover Crop Application) for the Soybean-Spring Cereal Cover Crop-Corn Management Systems Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean Grain Corn Moisture Content (1991)(%)			T-test Results*	
Soybeans at 10% Leaf Drop Sites					
	Barley	Oats	Control	Barley	Oats
Site 1	25.5	25.5	24.8	**	**
Site 2	19.2	20.3	20.3		
Site 3	17.2	17.3	17.2		
Mean of Sites 1, 2 & 3	20.6	21.0	20.8	No	No

Site	Kippen Barley	Leger Barley	Chapais Barley	Control	T-test Results*: Kippen Barley
Soybean Harvest Sites					
Site 4	20.9	-	20.7	19.5	**
Site 5	21.6	21.8	-	21.8	
Mean of Sites 4 & 5	21.3	21.8	20.7	20.7	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).
** Unable to complete t-test analysis on individual sites due to lack of replicated data.

Table 4.6.2.2: Results of the Grain Corn Moisture Content at Harvest (Year of Cover Crop Application) for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project. Cover Crop Studies I and II, 1990-1991.

Site	Mean Grain Corn Moisture Content (1990) (%)				T-test Results*		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	22.2	23.0	23.3	23.4	***	***	***
C/S**	23.2	21.8	23.9				
Site 2	23.4	22.5	23.1	23.0			
Site 3	28.7	27.1	27.6	28.2			
Site 4	28.9	28.7	28.4	28.2			
Site 5	35.9	35.6	37.1	35.1			
Mean of Sites 1, 2 & 3†	24.4	23.6	24.5	24.9	No	Yes	No
Mean of Sites 4 & 5‡	32.4	32.2	32.8	31.7	Yes	No	No
Mean of all Sites	27.1	26.5	27.3	27.6	No	No	No

* Yes = significant, no = no significant differences between treatment and control areas (P≤0.05).
** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.
*** Unable to complete t-test analysis on individual sites due to lack of replicated data.
† Herbicides applied in bands at these sites.
‡ Organically managed farms.

Table 4.6.2.3: Results of the Soybean Harvest Moisture (Year Following Cover Crop Application) for the Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System Project. Cover Crop studies I and II, 1990-1991.

Site	Mean Soybean Seed Moisture Content (1991) (%)				T-test Results*		
	Annual Ryegrass	Rodeo Barley	Leger Barley	Control	Annual Ryegrass	Rodeo Barley	Leger Barley
Site 1 S/C**	13.5	13.4	13.2	13.3	***	***	***
C/S**	13.4	13.4	13.2				
Site 2	15.1	15.4	14.6	15.0			
Site 3	12.9	12.9	13.0	13.0			
Site 4	15.0	14.9	14.9	15.9			
Site 5	11.7	11.6	11.4	11.7			
Mean of Sites 1, 2 & 3†	13.7	13.8	13.5	13.8	No	No	No
Mean of Sites 4 & 5‡	13.4	13.2	13.2	13.8	No	No	No
Mean of all Sites	13.5	13.6	13.4	13.8	No	No	No

* Yes = significant, no = no significant differences between treatment and control areas ($P \leq 0.05$).

** S/C = Cover crop seeded prior to interrow cultivation; C/S = Interrow cultivation followed by cover crop seeding.

*** Unable to complete t-test analysis on individual sites due to lack of replicated data.

† Herbicides applied in bands at these sites.

‡ Organically managed farms.

Table 4.6.2.4: Results of the Grain Corn Harvest Moisture (Year of Cover Crop Application) for the Barley, Oats ad Annual Ryegrass Management System Project, Annual Ryegrass Treatment Sites. Cover Crop Studies I and II, 1990-1991.

Site	Mean Grain Corn Moisture Content (1991)(%)				T-test Results*		
	1/2 X	1X	2X	Control	1/2X	1X	2X
Site 1	17.3 (0.7X)†	17.5 (1.2X)	17.4 (3.9X)	17.3	***	***	***
Site 2**	35.0 (0.5X)	34.7 (1.1X)	36.5 (1.9X)	36.3			
Site 3	17.2 (1.0X)	17.6 (1.4X)	17.1 (2.5X)	17.3			
Mean of Sites 1 & 3	17.3 (0.9X)	17.6 (1.2X)	17.3 (3.2X)	17.3	No	No	No
Mean of all Sites	23.2 (0.7X)	23.3 (1.3X)	23.7 (2.8X)	23.6	No	No	No

* Yes = significant, no = no significant differences between treatment and control areas ($P \leq 0.05$).

** Site 2 was planted as a silage corn crop but was harvested as a field corn crop and therefore had a much higher moisture content at harvest.

*** Unable to complete t-test analysis on individual sites due to lack of replicated data.

Statistical analysis of the data at site 4 revealed that the annual ryegrass had a significant effect on three of the measured parameters (Table 4.7.1) in the corn-spring cereal and annual ryegrass cover crop-soybean management system project. These same differences were not found at site 5 and may be attributable to the differences in the annual ryegrass seeding rate and/or the variation in tillage practices carried out to prepare the seedbed.

At site 4 the volume of water runoff, soil loss and sediment phosphorus loss decreased by 6.3 l/m^2, 2 g/m^2 and 2.5 g/m^2, respectively, as a result of the annual ryegrass treatment when compared to the control plots.

In general, the differences in the rainfall simulation results among sites may be related to management practices which can involve a variation in the type and number of tillage practices. Soil type differences may also be a factor to consider.

Table 4.7.1: Rainfall Simulation Results Conducted in 1991 for Selected Sites From the Cover Crop Studies I and II 1990-91 as Adapted From ESP (unpublished data).

Site and Treatment	Slope (%)	Residue Cover (%)	Soil Moisture (%)	Runoff Volume (L/m^2)	Soil Loss (g/m^2)	Sediment P Loss (mg/m^2)	Soluble Ortho P Loss (mg/m^2)
Project: Soybean-Spring Cereal Cover Crop-Corn Management Systems							
Site 3†							
Barley	2.6a*	24a	20.2b	5.8a	4.9a	5.5a	0.53a
Control	3.0a	21a	22.4a	10.0a	8.9a	10.5a	0.46a
Project: Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management System							
Site 4‡							
Annual Ryegrass	2.1a	16a	29.5a	1.3b	0.3b	0.37b	0.20a
Control	1.9a	9b	32.1a	7.6a	2.3a	2.89a	0.42a
Site 5**							
Annual Ryegrass	2.5a	28a	11.6a	7.9a	0.8a	0.98a	0.29a
Control	2.8a	25a	16.4a	5.0a	0.7a	0.92a	0.05a

† Rainfall simulation conducted on May 2-3, 1991 at an intensity of 155 mm/hr for 15 minutes.
* Means from the same site in the same column with different letters are significantly different at the 0.10 probability level.
‡ Rainfall simulation conducted on June 5-6, 1991 at an intensity of 155 mm/hr for 15 minutes.
** Rainfall simulation conducted on May 21-22, 1991 at an intensity of 155 mm/hr for 10 minutes.

5.0 COOPERATOR FEEDBACK

A general form was sent out to each of the cooperators for their feedback with regard to the cover crop projects. The following documents the cooperators response for each of the questions.

Question 1:
Did changing a management practice as a result of the cover crop study (i.e. no fall tillage, etc.) create any problems? Why?

The majority of the cooperators felt that no fall tillage was not a problem. Four of the respondents practised no-till, so leaving the ground unworked was common practice for these producers. The remaining cooperators with a 'no' response, all of whom tilled their land in the spring, were interested to see what affect spring tillage would have on their land.

Two cooperators thought that the cover crop work interfered somewhat with their normal management practices. From previous experience, one cooperator felt that the land should be worked in the fall to achieve full productivity. On the other hand, the remaining cooperator did not till the area and found it difficult to no-till plant into the high residues left from the corn (this cooperator participated in the underseeding of barley and annual ryegrass into corn project). The cooperator also felt that his equipment was inadequate to perform under a no-till planting system.

Question 2:
Did you notice any differences between the various cover crop treatments with regard to erosion control, subsequent plant growth, weed control, soil tilth, seed bed preparation, etc.?

The response to this question was related to the specific cover crop project and is presented as such.

Project: Soybean-spring cereal cover crop-corn management systems

In general, the comments from the cooperators indicated there were no differences between the treatments. However, one cooperator observed that the barley achieved more growth

than oats in the fall (based on the 10% soybean leaf drop application). A common response among cooperators was that there was very little residue apparent on the soil surface in the spring from any of the treatments.

The cooperators involved in the soybean harvest application of the cover crops stated that 'since they were already practising no-till, the use of a cover crop did not add to the erosion control of the field.'

No comments were solicited with regard to corn growth the following year.

Project: Corn-spring cereal and annual ryegrass cover crop-soybean management system

Only one cooperator felt that the annual ryegrass gave excellent control of soil erosion and weed growth. Incidently, this cooperator would be categorized as an organic producer since he does not use commercial pesticides, fertilizer or seed varieties.

The remaining cooperators felt there was no difference in the aforementioned parameters with regard to the various treatments, although they all noted the good top growth of the annual ryegrass. One cooperator commented that the annual ryegrass growth should add to the soil tilth.

None of the respondents indicated any affect on the subsequent soybean crop growth.

Project: Barley, oats and annual ryegrass management systems

Due to the lack of precipitation after the cover crop application of the annual ryegrass into corn in 1991 the growth of this cover crop was reduced compared to the annual ryegrass growth achieved in 1990. Therefore, the participating cooperators felt there was little, if any, difference between the application rates with regard to effective erosion control and other parameters.

The growth of the cereal cover crops also seemed to be related to the timing and amount of precipitation received at each site in 1991. All of the cooperators could tell a distinct difference between the application rates (1/2X, 1X and 2X) of either the barley or oat

treatments. Although the majority felt the growth, even at the 2X rate, would be insufficient to affect erosion control and soil tilth.

It was unreasonable to expect the cooperators to comment on the effect of the cover crop on seedbed preparation, weed control and subsequent crop growth since the survey was conducted in the fall of 1992.

Question 3:
What benefits do you see as a result of using cover crops on your farm?

Some of the possible benefits mentioned by the cooperators included:
- reduced wind and water erosion;
- increased organic matter content;
- nutrient recycling including nitrogen contribution from legumes;
- increased soil structure stability; and
- reduced weed growth.

One cooperator, in particular, noted that cover crops should be used with field bean crops as opposed to grain corn while another remarked that cover crops would be useful in silage corn rotations.

For those cooperators presently using no-tillage farming practices, no benefits were perceived. They felt that no-till provided them with erosion control, nutrient recycling, increased organic matter content and soil structure stability.

Question 4:
What drawbacks do you see as a result of using cover crops on your farm?

The most frequent drawback pointed out by the cooperators was the extra cost of applying the cover crop. The cost was seen to include the time it takes to apply the cover crop, extra seed cost and extra herbicide costs (if required).

Other areas of concern were loss of current and subsequent crop yield. Some mentioned the trampling of soybeans at time of application as a drawback while others felt the yields

of subsequent crops would be reduced either from insect damage (i.e. slugs), possible allelopathic effects or as result of not fall ploughing. It was also stated that the ground may be cooler in the spring with the use of cover crops which has the potential to affect the time of planting and rate of seed germination.

One cooperator perceived problems with weed control and handling of trash. However, this problem may be more related to switching to a no-till system than using cover crops.

On a positive note, three cooperators implied that the benefits outweighed the drawbacks.

Question 5:
What changes, if any, would you recommend with regard to the timing and/or method of application of the cover crop?

The majority of the cooperators involved in spreading the cereal cover crop into soybeans would like to utilize a method that did not damage the soybeans. Alternate suggestions included tramlines or aerial application. They also commented that the size of the spreader (volume) and spreading pattern should both be increased if using a ground application method for field scale. One cooperator involved in this project commented that he had better success drilling cover crops as opposed to broadcasting in terms of cover crop growth.

The most common suggestion in terms of applying the annual ryegrass into the corn was to have the spreader mounted on the interrow cultivator and spread the seed at the last cultivation. This was the initial proposed method of application but changes were made to accommodate each of the cooperators set-up.

In both types of studies many of the cooperators felt that the cover crop seed could have been applied earlier, either into the soybeans or corn.

Question 6:
In relation to cover crops, what future research would be of interest to you (please take into account crop, method of application, type of data collected, etc.)?

The most frequent comment solicited by the cooperators involved nitrogen. Whether it be

nitrogen contribution of the cover crop (legumes), nitrogen retained by the cover crop or the timing of nitrogen release of the various leguminous cover crops.

As mentioned earlier, many of the cooperators felt that cover crop work into field beans or silage corn would be more applicable than into grain corn.

Additional comments with regard to this question included: the use of winter rye for weed suppression; measuring cover crops for their organic matter contribution; monitoring the interaction of legume cover crops with cereal residues and its effect on subsequent corn growth; and timing and method of application (broadcasting versus drilling) of various types of cover crops.

Another comment was made on relay cropping which theoretically utilizes a cover crop such as winter rye or winter barley broadcast into soybeans in late summer. This cover crop would be left to grow until late May and removed as hay, followed by the planting of another crop such as field beans.

Question 7:
In general, what future on-farm research would be of interest to you?

The following is a list in point form of the areas where the farmers would like to see research carried out.

- Sustainable agriculture - this can involve practical organic farming on an economical scale to the organic production of speciality crops such as white, pinto, kidney or soybeans.

- To determine why no-till planting corn into winter wheat stubble causes problems to many farmers. Is it related to residue management (cutting height, spreading and/or removal of the straw), allelopathic affects, ground temperature, etc.?

- To determine if legumes are of value in reducing the growth inhibition affects of wheat/oats/rye residue on the following no-till corn crop. This may be related to the above point.

- Tillage research whether it be no-till, reduced tillage or ridge tillage.

- A way to determine weed pressure before plants appear as opposed to waiting to see what germinates.

- Develop a economical spray program (related to above point).

- Assessment of the time span required in no-till crop rotations to break common disease cycles.

- To determine the optimal kill date of cover crops (especially legumes) to reduce nitrogen loss to ground water.

- The effect of working in lime into the soil on macropores. How long does it take to rebuild the macropores?

6.0 COST ANALYSIS

A cost comparison of the various treatments at the recommended rates is tabulated for the corn-spring cereal and annual ryegrass cover crop-soybean and the soybean-spring cereal cover crop-corn management system projects in Table 6.1. Because the cost of seeding is not directly recoverable by the producer, the economical choice of cover crop will be the cheapest seed cost combined with the greatest erosion control benefits.

The annual ryegrass seed cost is substantially lower at $23.25 per hectare, than even bin run oats and barley. However with bin run cereals, one cannot count on as high a germination rate as with certified seed, therefore the cost may actually increase from the $30 to $32 a hectare already figured for untreated bin run cereal seed. The cost of certified cereal seed from a retailer ranged from $54 to $68 per hectare to seed at the rates used in this study and would be too prohibitive for most producers. Thus, the erosion control benefits would be seriously outweighed by the economics of certified seed costs when using spring cereals as a cover crop.

Taking into consideration the rainfall simulation results and seed cost, annual ryegrass would be the obvious choice for the producer.

Table 6.1: Seed Cost Comparison of Annual Ryegrass, Spring Barley and Spring Oats Based on Recommended Rates of Application in the Cover Crop Studies I and II, 1990-1991.

Species and Variety	Source	Cost	
Annual Ryegrass	**Canada No.1**	Recommended Rate 15 kg/ha	
Annual	W.G. Thompson	$1.55/kg	$23.25/ha
Barley	**Certified Seed**	Recommended Rate: 165 kg/ha	
		$/25 kg	$/ha
Leger	W.G. Thompson	10.25	67.65
	W.G. Thompson	9.75	64.35
Rodeo	W.G. Thompson	8.50	56.10
Chapais	Secan Dealer	8.25	54.45
	W.G. Thompson	8.50	56.10
Kippen	Secan Dealer	8.25	54.45
Any variety	**Bin Run**		
	Treated	6.80	44.88
	Untreated	4.75	31.35
Oats	**Certified Seed**	Recommended Rate: 150 kg/ha	
		$/25 kg	$/ha
Ogle	W.G. Thompson	9.50	57.00
	Secan Dealer	9.25	55.50
Any variety	**Bin Run**		
	Treated	7.05	42.30
	Untreated	5.00	30.00

7.0 DISCUSSION

Weather conditions played a critical role in the outcome of the cover crop studies.

In 1990 the mean monthly temperatures were similar to those of the 20 year average, however precipitation amounts were considerably higher especially in the months in which the cover crops were applied. In July, the amount of precipitation was approximately 226% higher than the 20 year average for all sites where barley and annual ryegrass seed were spread into corn. In 1990, when the spring cereals were broadcast into soybeans at 10% leaf drop (September) the precipitation averaged 157% higher than would normally be expected. This above normal precipitation around cover crop application dates may account for the good cover crop growth produced at each of these sites.

However, the persistence of the wet weather for much of September and October in 1990 delayed soybean harvest. As a result the spring cereals were broadcast into the soybeans later in the year than anticipated in order to achieve maximum plant growth.

In the spring of 1991, above average air temperatures were recorded for all sites. As a result corn development and growth progressed more rapidly than usual which made it difficult to find sites with corn at the appropriate growth stage. In contrast to 1990, the precipitation in the months of cover crop application were lower than the 20 year average. In June, when the annual ryegrass was broadcast into corn the average reported precipitation was 37% of the 20 year average. The combination of high temperatures and low precipitation had a dramatic effect on the annual ryegrass productivity especially when compared to the annual ryegrass growth achieved in 1990.

When the spring cereals were applied to the soybeans precipitation was 43% lower than normal which affected the rate of germination and growth of the cover crop.

With regard to site management conditions only slight deviations from the norm occurred. Soybean leaf drop ranged from 10 to 80% with the majority of the spring cereals being broadcast into soybeans at approximately 10% leaf drop. As mentioned earlier soybean harvest was delayed because of weather in 1990. As a result this portion of the study was implemented later than planned.

The ryegrass applied to the plots was considered to be an annual. However in the spring of 1991 (year following cover crop application) much of the annual ryegrass was still alive and growing. It was also noted that some barley plants that were broadcast into soybeans had overwintered. Herbicide or tillage treatments were required to control this unexpected growth of the cover crops.

Due to the nature of the spreading pattern on the Herd® broadcaster, variability in the seeding rates was apparent even though numerous calibrations were undertaken prior to seed application. A miscommunication between one cooperator and his father resulted in a corn field being accidentally moldboard ploughed before dry matter and after harvest residue levels could be collected. This field contained an annual ryegrass seeding rate trial in 1991.

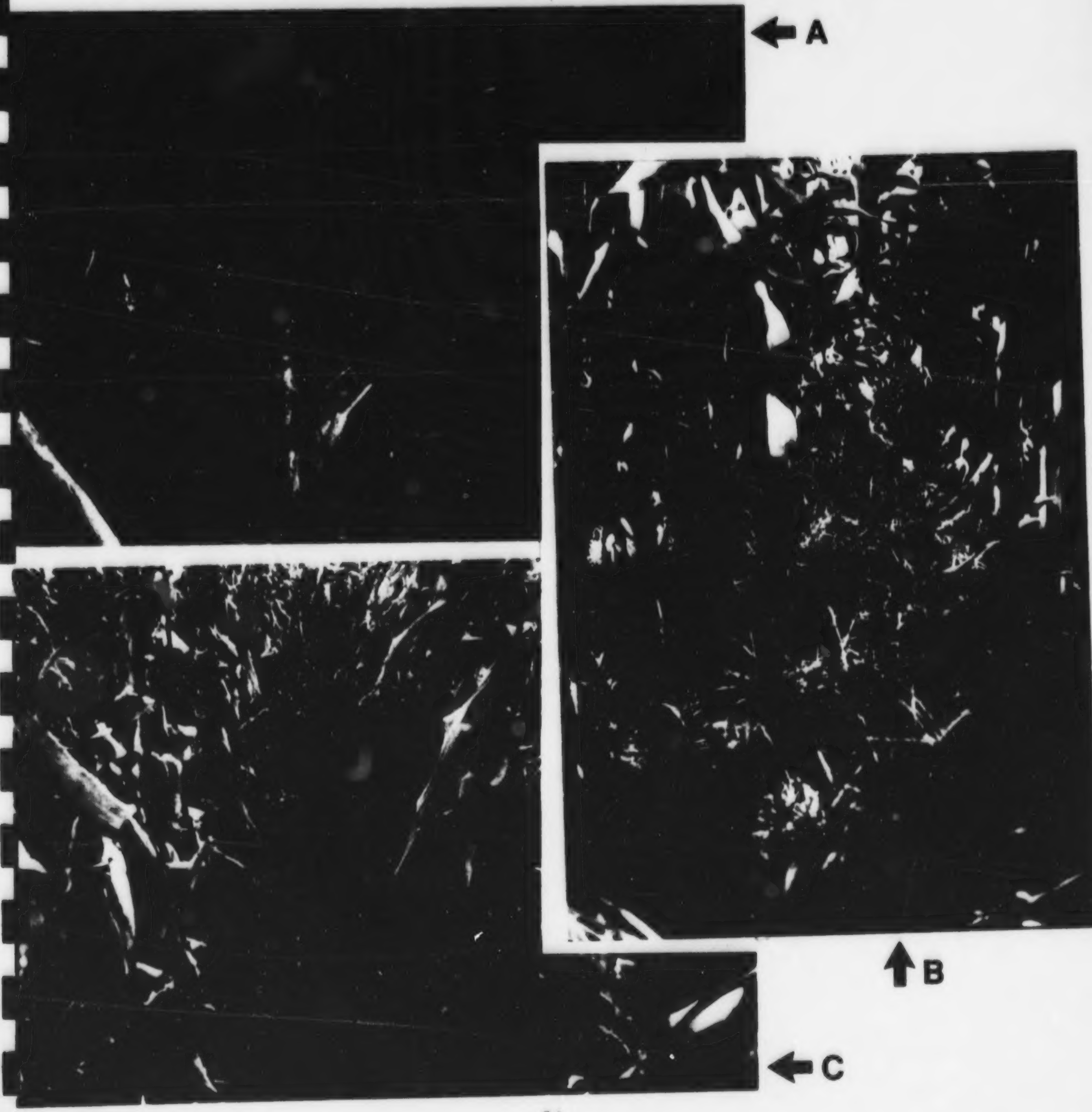
The amount of damage caused to the row crop by applying the cover crop was more severe in the soybeans than corn. The amount of damage to the soybeans was related to the width of the tractor wheel; width of soybean row; and whether the plants were standing or lodged. In 1991 two of the corn sites had corn plants that were over one metre in height and a few stalks were broken as the tractor passed over the row while applying the annual ryegrass treatments. The corn plants were also under stress conditions from lack of adequate precipitation which made them more brittle and thus more susceptible to breakage.

Although not clearly explained by the type of data collected in 1990, visual observations indicated that the barley cover crop treatments applied to the corn in 1990 resulted in less than satisfactory growth under band sprayed conditions. The early growth of the barley was vigorous but as the corn canopy closed in the plants started to die back. By harvest very little evidence of barley cover crop growth was apparent. In contrast the annual ryegrass early growth was slow but improved as the season progressed. By harvest, a lush top growth of annual ryegrass was observed. Figures 2 and 3 illustrate the sequence of growth stages of both the barley and annual ryegrass under band sprayed conditions.

Under organically managed conditions in 1990 both the barley and annual ryegrass thrived throughout the growing season. This growth may be related to the less competitive nature of the corn crop grown under these conditions (-5.54 Mg/ha yield difference compared to the band sprayed sites).

Figure 2: Illustration of Barley Underseeded Into Corn in Early July. A = Early Growth; B = Mid-season Growth; C = Late Season Growth.

Figure 3: **Illustration of Annual Ryegrass Underseeded Into Corn in Early July. A = Early Growth; B = Mid-season Growth; C = Late Season Growth.**



In the first year of this study spreading oats into soybeans at 10% leaf drop increased after harvest and after spring runoff residue levels relative to the control while the barley treatment had no significant effect. After planting residue levels showed no residual effects of either cover crop (oats or barley) being applied the previous year.

The barley seed broadcast into soybeans just prior to harvest produced very little top growth by late fall. Thus it was expected that this minimal amount of growth would not affect residue levels. In addition these sites have been managed as no-till fields for at least the past five years, therefore a cover crop would have to produce large amount of growth in order to significantly increase the residue levels under these conditions.

Over all sites the annual ryegrass was the only cover crop treatment applied into corn that resulted in significantly more residue after harvest, after spring runoff and after planting than the residue found in the control area. The Leger and Rodeo barley treatments were also found to produce significantly more residue after harvest and after spring runoff, respectively, compared to the control. It is interesting that the barley treatments would have any effect on residue levels since very little top growth was evident by the end of the establishment year except at the organically managed sites.

In 1991, applying annual ryegrass into corn at any of the rates did not provide any benefits with respect to after harvest residue levels. Seeding barley at any of the treatment levels into soybeans resulted in significantly higher residue levels than the control area after harvest. Therefore broadcasting the barley at 1/2X the recommended rate (actual rate of application was 23% above the 1/2X expected rate) was sufficient to increase residue levels compared to the control. Using oats required the 1X treatment (actual seeding rate was 1.2X) to produce enough residue to significantly increase the residue level after harvest.

With regard to cover crop plant emergence the annual ryegrass treatment had more seedlings emerged three weeks after planting than either the Leger or Rodeo barley treatments. These results were expected as the seed size of annual ryegrass is considerably smaller than that of the barley, therefore more seeds would be applied per unit area.

In general, the number and species of weeds were not affected by any particular cover crop in 1990-1991. However at one of the organically managed sites the number of weeds were

reduced by about one half in the spring compared to the fall under the Leger barley and annual ryegrass treatments. In the barley, oats and annual ryegrass management system project sites very few weeds were counted in any of the treatments including the control.

Above ground biomass samples were collected for the barley, oats and annual ryegrass management system project sites in the fall of 1991. In general for the spring cereals more biomass was accumulated in the barley treatments than in the oat treatments. The 2X seeding rate treatments of the cereals consistently produced significantly more biomass than either the 1/2X or 1X treatment. The annual ryegrass seeding rate treatments produced the least amount of dry matter of all the treatments which may be a result of the low levels of precipitation at seeding time. Visual observations of the residue accumulated in 1990 indicate that the annual ryegrass produced considerably more top growth by fall than in 1991 while the spring cereal treatments achieved slightly more top growth than in 1991.

No matter what management practice (band spraying, organic or no-till), method of application (corn vs. soybeans) or cover crop species (annual ryegrass, barley, or oats) the effect on crop yield was the same. No significant differences were detected when the sites were combined, whether it was the year of cover crop establishment or the year following.

The moisture content of the corn in the year of cover crop establishment varied with management practices in the corn-spring cereal and annual ryegrass cover crop-soybean management system project. Under band sprayed conditions the Leger barley treatment reported a significantly lower corn moisture content than the control. Whereas under organically managed conditions the annual ryegrass measured a slightly higher, although significant corn grain moisture content than the control. No differences in the seed moisture contents were reported for the remaining treatments.

For the cover crop comparisons made using rainfall simulation only the annual ryegrass treatment at one site reported substantial decreases in water runoff volume, soil loss and sediment phosphorous loss when compared to the control area.

With regard to the cooperator feedback results a few interesting items were noted by the cooperators. The majority felt that using a cover crop did not affect their management practices which mainly included the use of no fall tillage. However most felt that the cover

crop did not have a significant effect on erosion control or weed pressure except for the annual ryegrass treatment applied in 1990.

Three of the fifteen cooperators responded that the benefits outweighed the drawbacks of using cover crops. The damage caused by driving into the soybeans while applying the cover crops was seen as a negative point and suggestions were made to alleviate this problem. On the other hand the majority of the cooperators felt that some possible benefits included reduced erosion, increased organic matter content and soil structure stability from using cover crops

In the future some of the areas where the cooperators would like to see research mainly focused on nitrogen. Whether it be nitrogen contributions of the cover crops (legumes), nitrogen retained by the cover crop or the timing of nitrogen release of various leguminous crops.

The seed cost analysis of the various cover crops used in these studies indicated that annual ryegrass would be the most economical choice when applied at the recommended rate of 15 kg/ha. The cost of bin run cereals was calculated to be about $7 more per hectare than annual ryegrass. However the cereals seemed to perform more consistently under less than ideal conditions such as drought.

8.0 CONCLUSIONS

1. In 1990, applying oats into soybeans at 10% leaf drop increased residue levels when compared to the soybean stubble alone through the winter and early spring. However in 1991 under similar conditions the barley performed better than the oats.

2. Practical considerations related to labour needs, weather and timing of cover crop establishment for adequate fall growth do not favour the planting of cereal cover crops at soybean harvest.

3. Applying the spring cereals above the recommended rate affected the amount of above ground dry matter accumulated but did not significantly increase the soil surface residue level.

4. Spreading the cover crop in the method utilized in this study resulted in damage to the soybeans. Alternative methods such as tramlines could be used in the future to lessen this impact.

5. Annual ryegrass applied into corn at the recommended rate and above was observed to provide sufficient top growth by late fall under both types of management conditions to increase residue levels compared to the control area in 1990. However in 1991, due to lack of precipitation the annual ryegrass did not achieve the expected growth as it did in 1990.

6. Under organically managed conditions the barley broadcast into corn performed better than under band sprayed conditions with respect to cover crop growth achieved by corn harvest. This growth may be related to the thinner stand of corn at these sites which allowed sunlight to penetrate and reach the barley plants throughout the season.

7. The use of cover crops under a no-till management system did not provide any further benefits than no-till alone.

8. With regard to weed control, no general trend for any of the cover crop treatments was apparent from the data collected in this study. However under organically managed conditions the Leger barley and annual ryegrass treatments reduced the number of weeds by approximately one half between harvest and late April.

9. In the annual ryegrass treatment runoff volume, soil loss and sediment phosphorus loss were decreased relative to the control area. These data were collected after planting in the year following cover crop establishment.

10. From a seed cost perspective the annual ryegrass was the most economical choice of the cover crops tested in this study.

9.0 RECOMMENDATIONS

1. The most logical choice of cover crop from those studied is annual ryegrass applied at the recommended rate with respect to seed cost, possible erosion control and increased residue levels.

2. Due to the unpredictable weather that occurs in Ontario around harvest broadcasting cover crops into soybeans just prior to harvest is not seen as being a feasible or practical undertaking.

3. If planning to apply a cover crop into soybeans at 10% leaf drop, it is recommended that tramlines be included at soybean planting to decrease the amount of soybean damage.

4. The use of spring cereals as a cover crop in a no-tillage system is not recommended as they provide no apparent additional benefits than no-till alone.

5. A literature review should be conducted to determine current estimations of the minimum soil cover and dry matter accumulations required to have a significant beneficial effect on soil erosion control, phosphorus loading, nutrient recycling, soil structure amelioration and weed control.

6. It is recommended that 'further research studies be carried out to determine the application of annual ryegrass as a cover crop under other cropping systems such as silage corn or field beans.

7. From the feedback received from the cooperators the use of legumes as a cover crop should be studied in detail. Areas of interest included legumes as a nitrogen source, timing of nitrogen release and nutrient recycling.

APPENDIX A

SOIL FERTILITY DATA

SOIL FERTILITY

Site	P	K*	Mg	Ca	pH
	ppm				
Project: Soybean-Spring Cereal Cover Crop-Corn Management Systems					
Site 1	23		221	3800	7.4
Site 2	32		172	4450	7.6
Site 3	39		281	3050	7.1
Site 4	29		167	2450	7.6
Site 5	29		255	2430	7.4
Project: Corn-Spring Cereal and Annual Ryegrass Cover Crop-Soybean Management Systems					
Site 1	60		182	850	6.6
Site 2	24		326	3475	7.2
Site 3	20		210	1880	7.1
Site 4	37		212	4900	7.6
Site 5	7		210	3510	7.8
Project: Barley, Oats and Annual Ryegrass Management System - Annual Ryegrass Sites**					
Site 1	38	114	150	1110	6.3
Site 2	36	120	168	2495	7.7
Site 3	28	142	154	1130	6.3

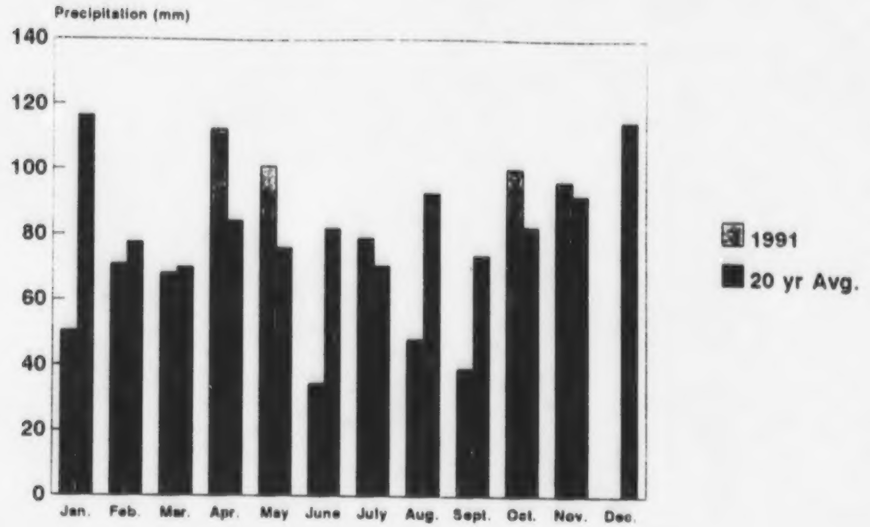
* K (Potassium) levels are unavailable for the 1990-1991 fall soil sampling event.

** Soil samples not taken for the oat and barley treatment sites.

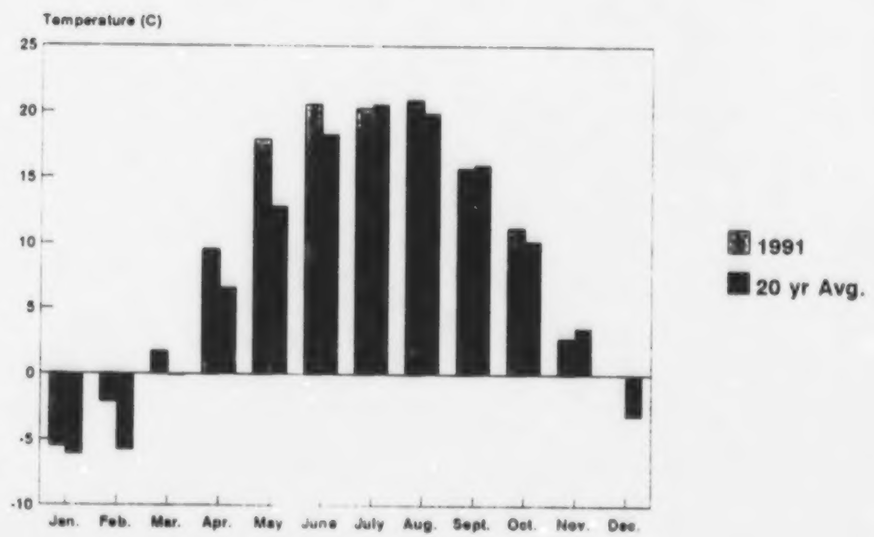
APPENDIX B

WEATHER SUMMARIES BY INDIVIDUAL SITE

Barley, Oats and Annual Ryegrass Management Systems
Precipitation Data: Barley Site 1

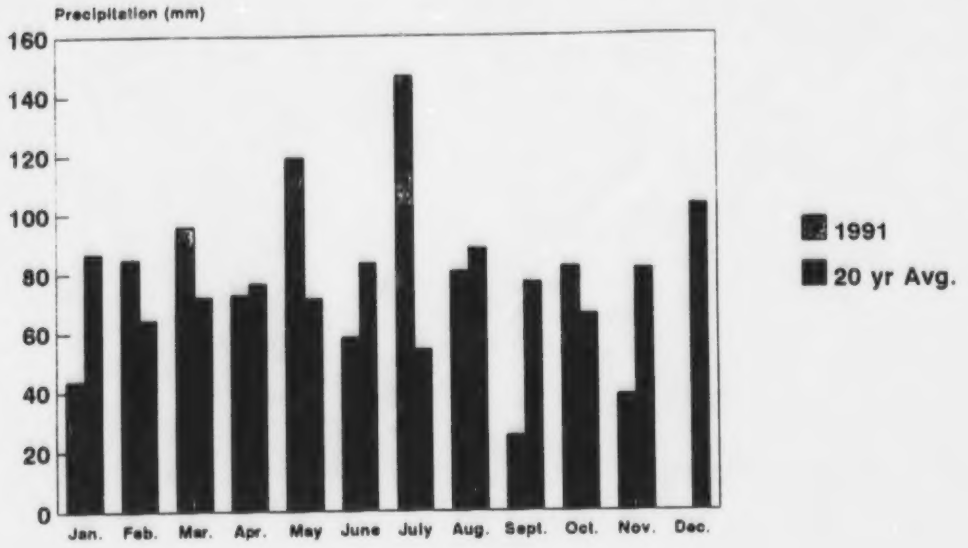


Barley, Oats and Annual Ryegrass Management Systems
Temperature Data: Barley Site 1

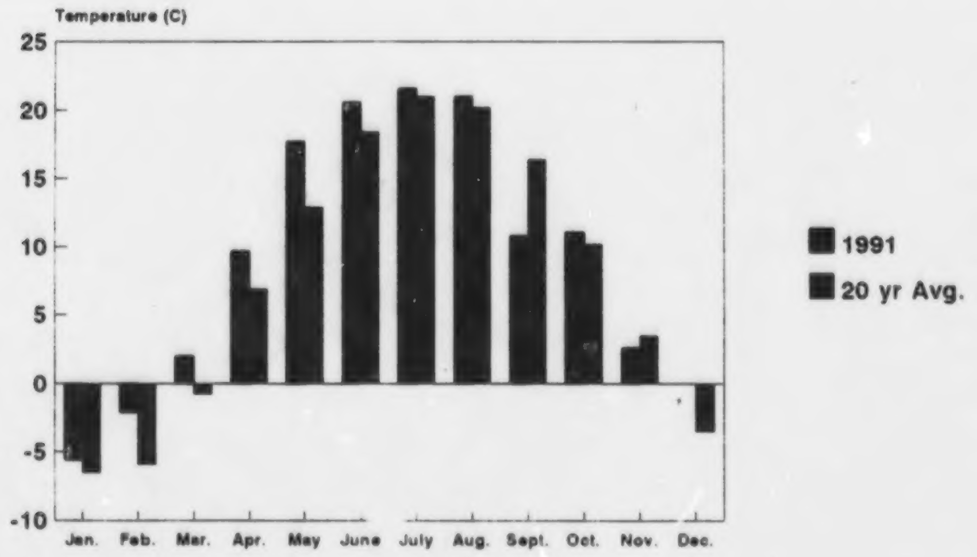


Source: Atmospheric Environment Service, Environment Canada
Centralia/Huron Park Weather Station

Barley, Oats and Annual Ryegrass Management Systems
Precipitation Data: Barley Sites 2 and 3
Oat Sites 1 and 3

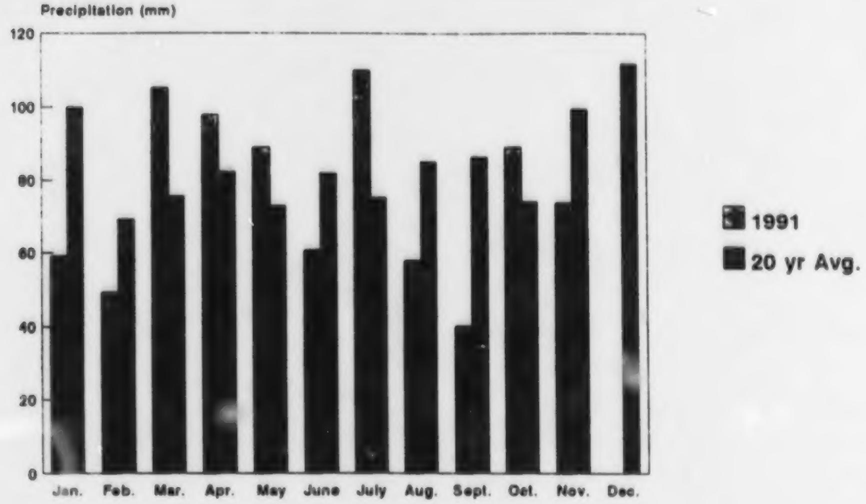


Barley, Oats and Annual Ryegrass Management Systems
Temperature Data: Barley Sites 2 and 3
Oat Sites 1 and 3

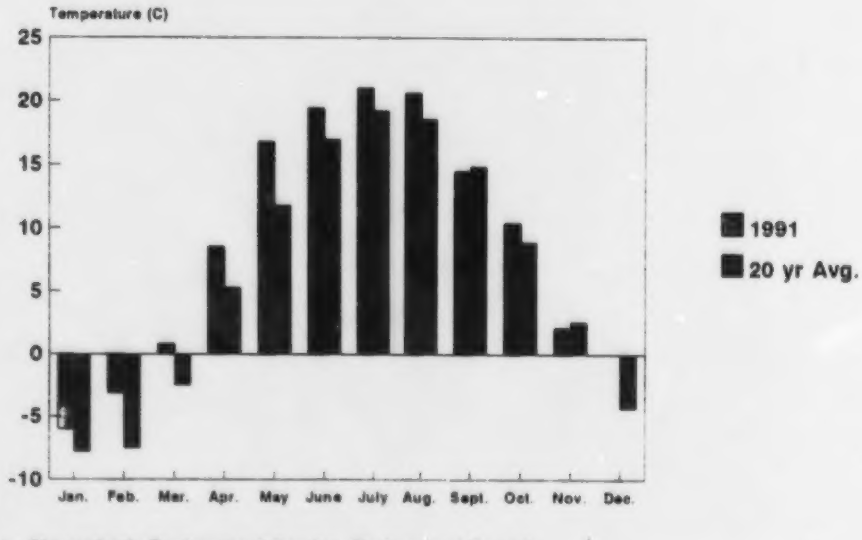


Source: Atmospheric Environment Service, Environment Canada
Ilderton Bear Creek Weather Station

Barley, Oats and Annual Ryegrass Management Systems
Precipitation Data: Annual Ryegrass Site 1

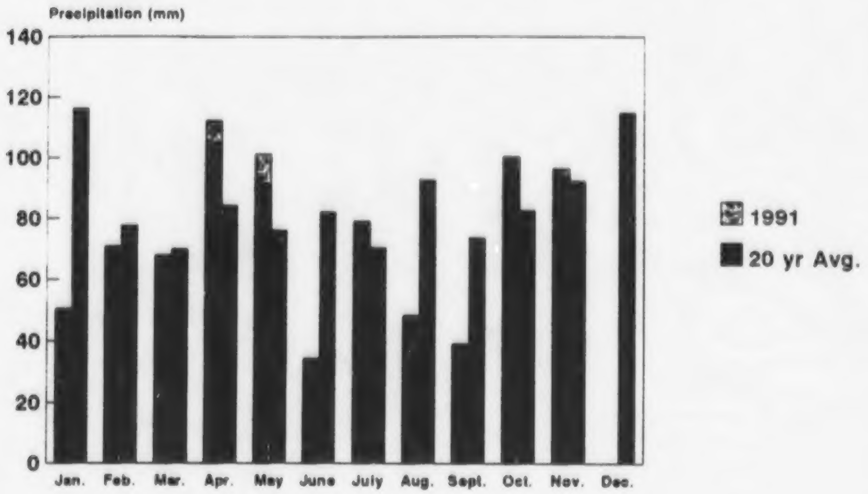


Barley, Oats and Annual Ryegrass Management Systems
Temperature Data: Annual Ryegrass Site 1

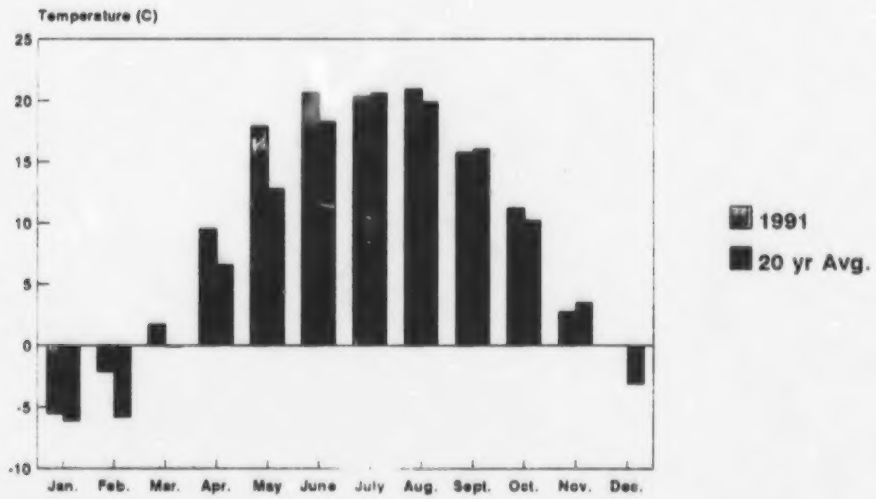


Source: Atmospheric Environment Service, Environment Canada
Stratford Weather Station

Barley, Oats and Annual Ryegrass Management Systems
Precipitation Data: Annual Ryegrass Site 2
Oat Site 2

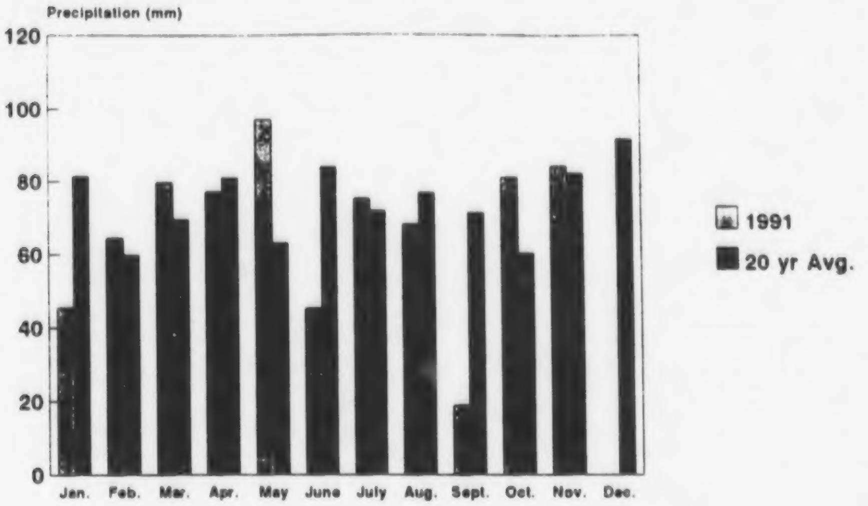


Barley, Oats and Annual Ryegrass Management Systems
Temperature Data: Annual Ryegrass Site 2
Oat Site 2

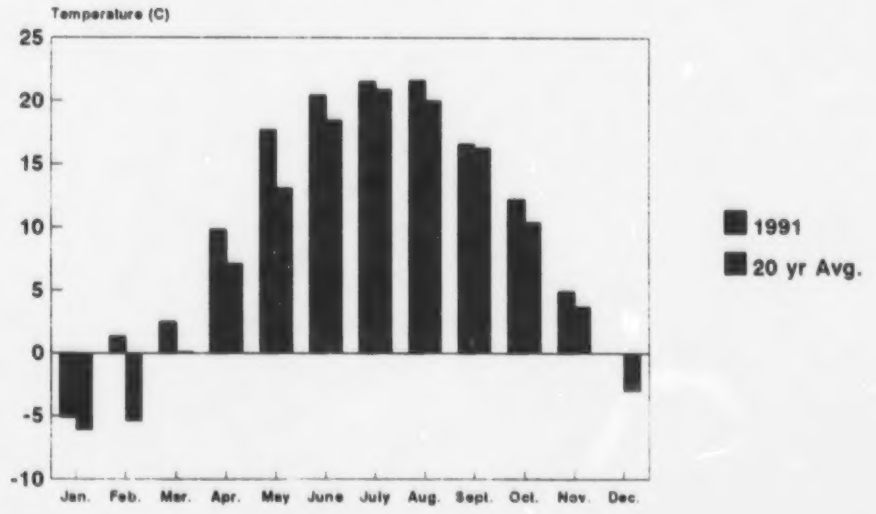


Source: Atmospheric Environment Service, Environment Canada
Centralia/Huron Park Weather Station

Barley, Oats and Annual Ryegrass Management Systems
Precipitation Data: Annual Ryegrass Site 3

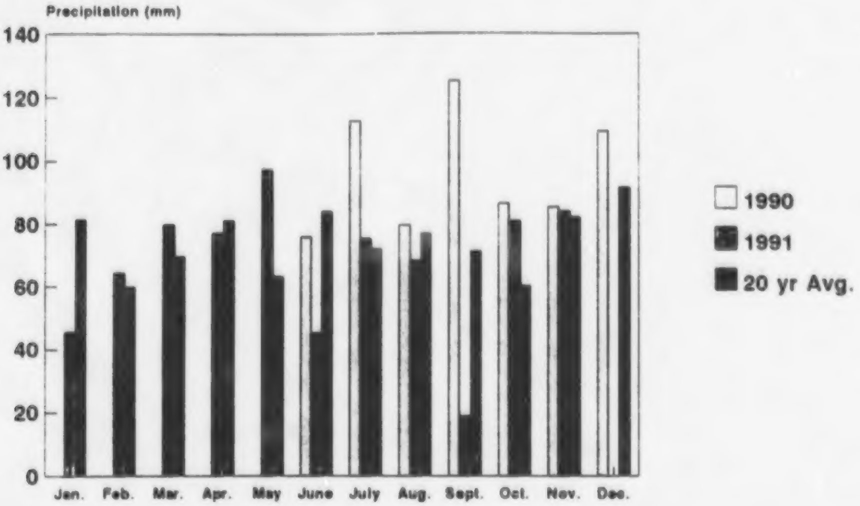


Barley, Oats and Annual Ryegrass Management Systems
Temperature Data: Annual Ryegrass Site 3

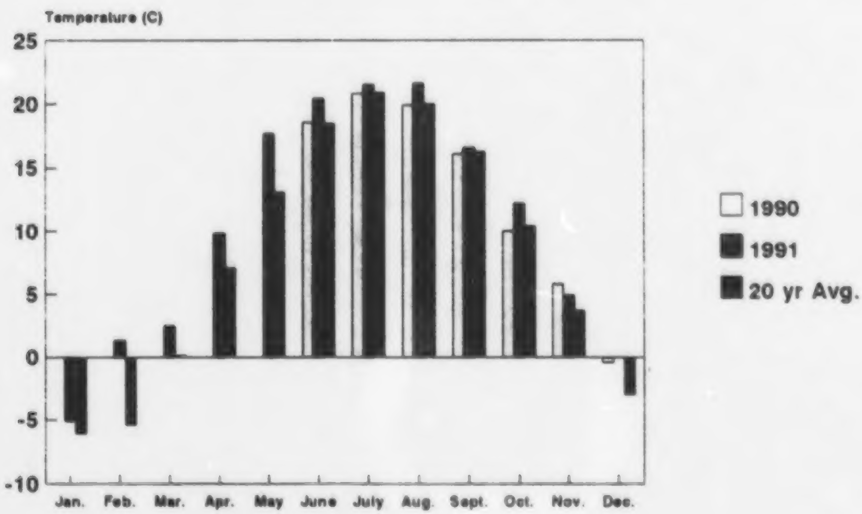


Source: Atmospheric Environment Service, Environment Canada
Strathroy Weather Station

Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Precipitation Data: Site 1

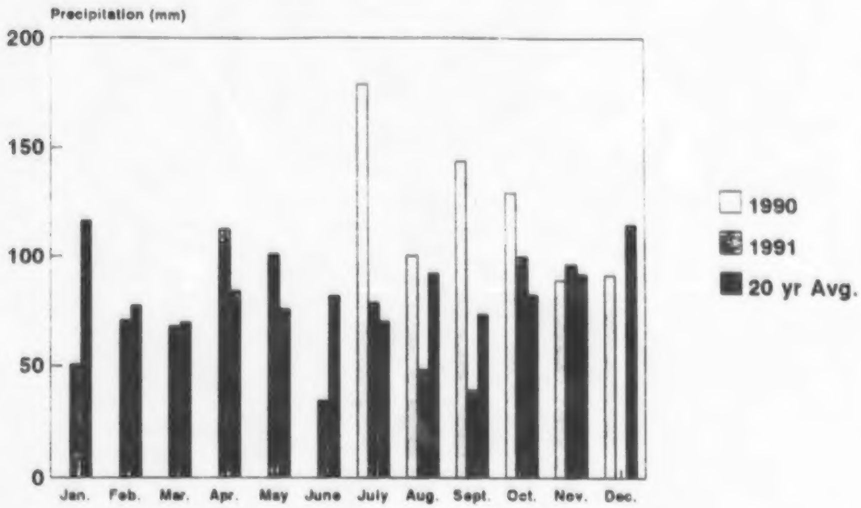


Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Temperature Data: Site 1

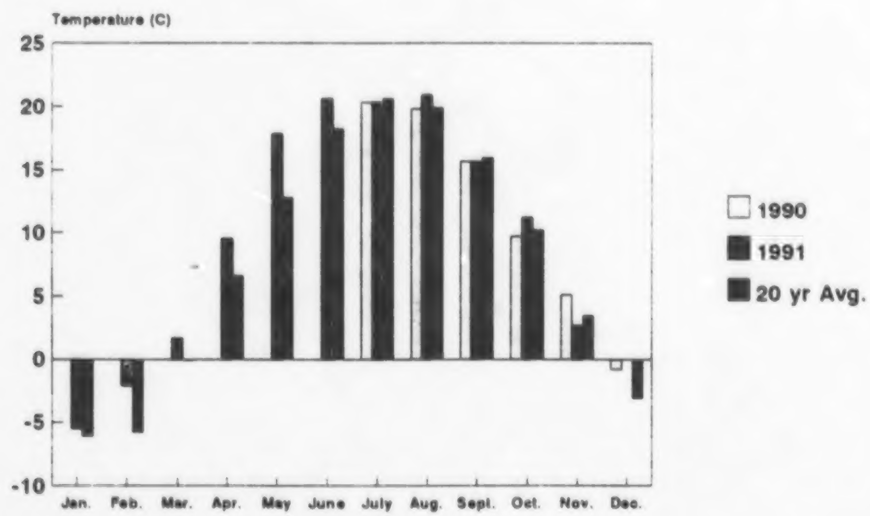


Source: Atmospheric Environment Service, Environment Canada
Strathroy Weather Station

Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Precipitation Data: Site 2

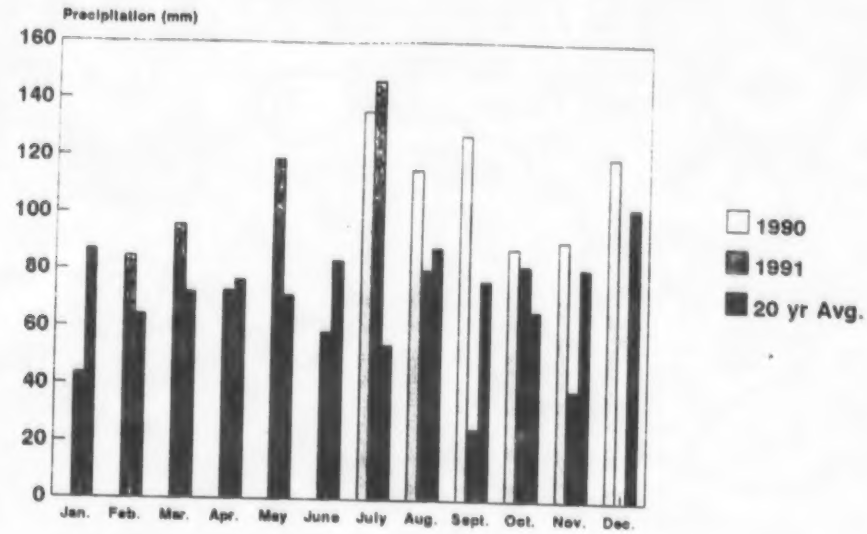


Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Temperature Data: Site 2

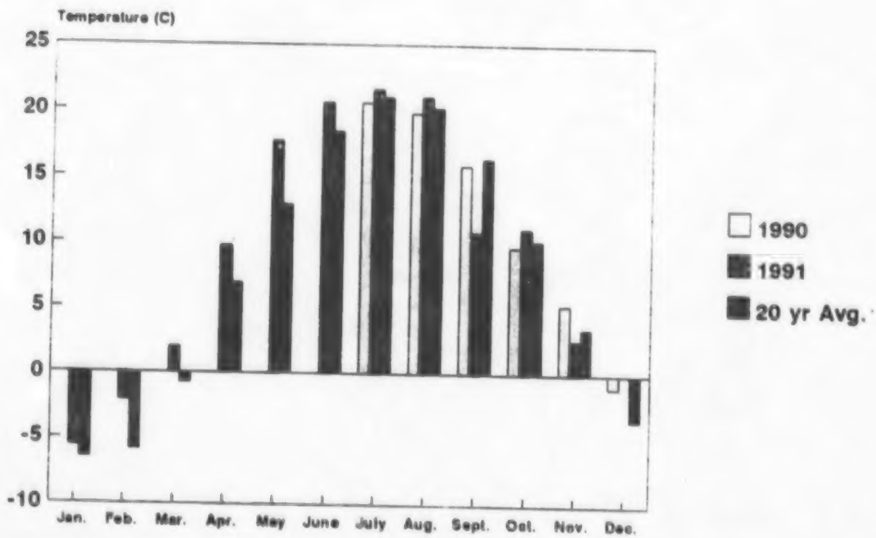


Source: Atmospheric Environment Service, Environment Canada
Centralia/Huron Park Weather Station

Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Precipitation Data: Site 4

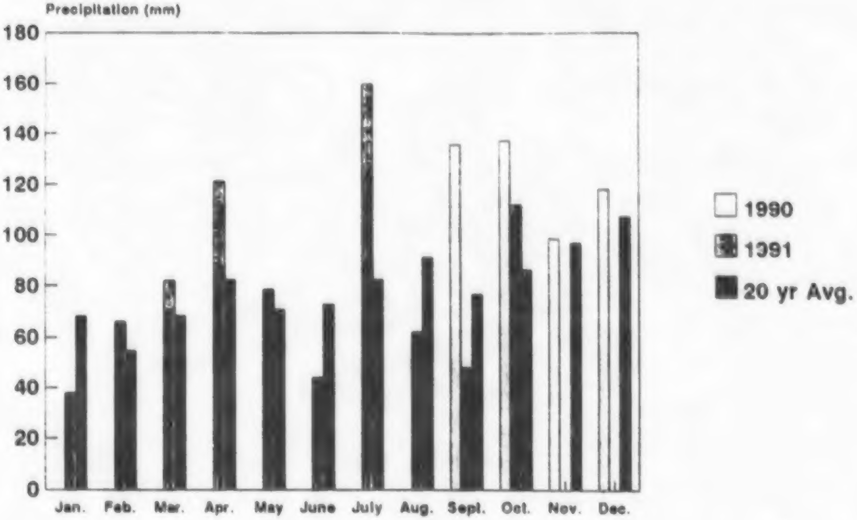


Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Temperature Data: Site 4

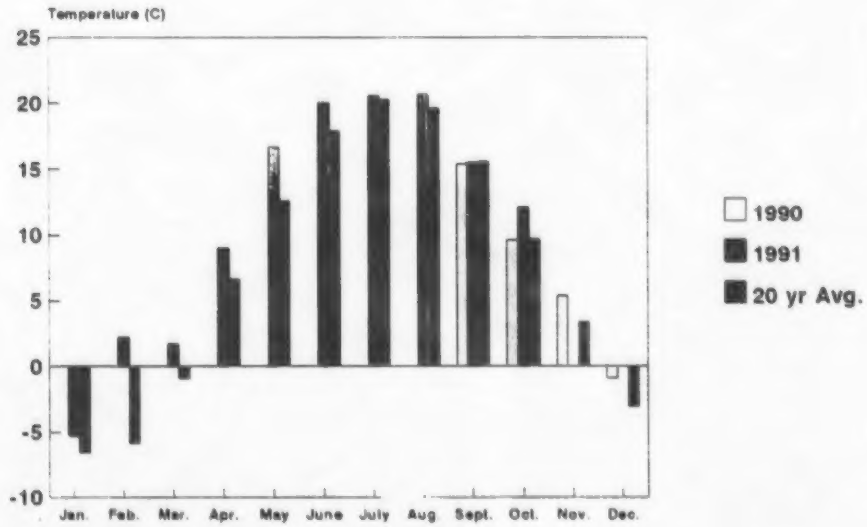


Source: Atmospheric Environment Service, Environment Canada
Ilderton Bear Creek Weather Station

Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Precipitation Data: Sites 3 and 5

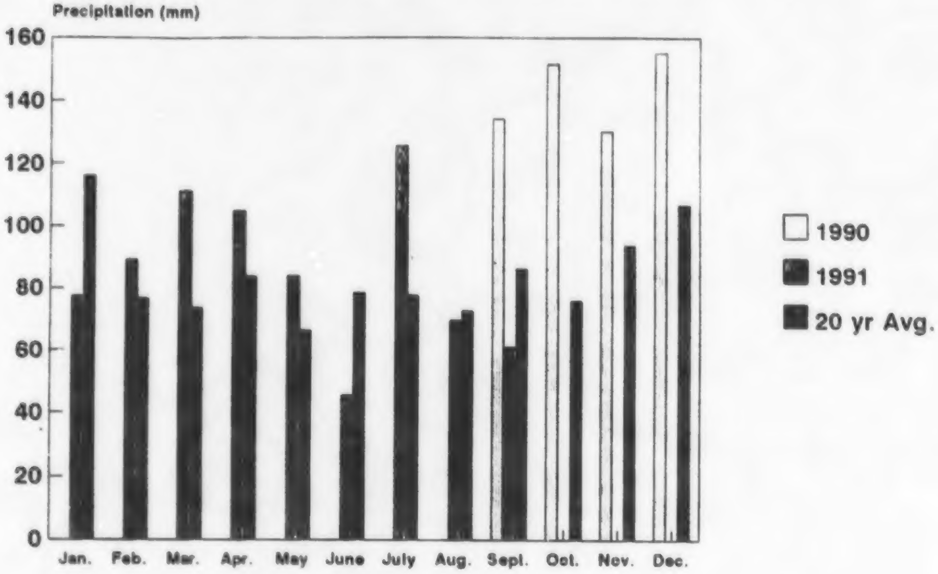


Corn-Spring Cereal and Annual Ryegrass-Soybean Management Systems
Temperature Data: Sites 3 and 5

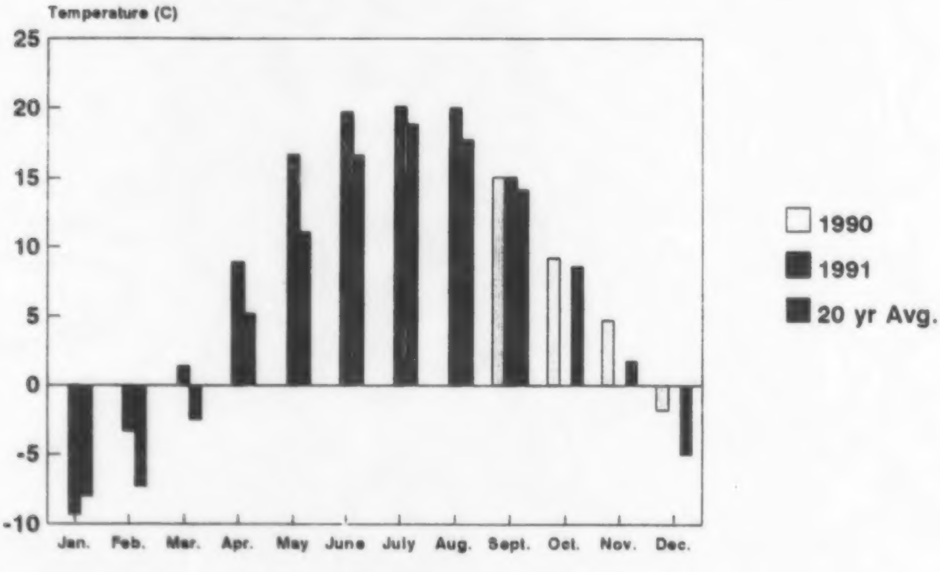


Source: Atmospheric Environment Service, Environment Canada
Dashwood Weather Station

Soybean-Spring Cereal Cover Crop-Corn Management Systems
Precipitation Data: Site 1

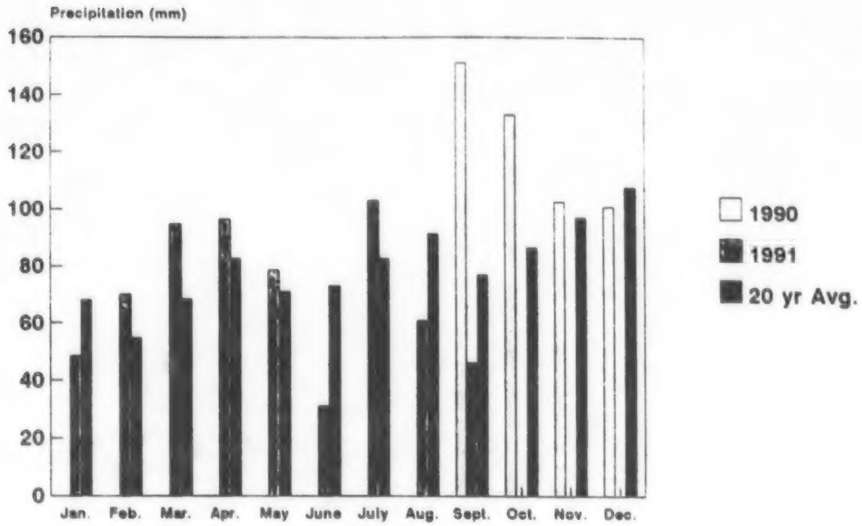


Soybean-Spring Cereal Cover Crop-Corn Management Systems
Temperature Data: Site 1

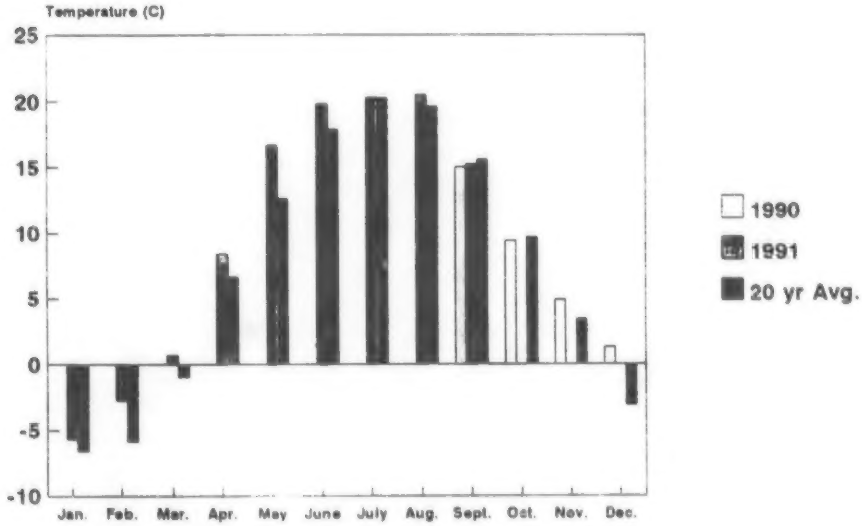


Source: Atmospheric Environment Service, Environment Canada
Cromarty Weather Station

Soybean-Spring Cereal Cover Crop-Corn Management Systems
Precipitation Data: Site 2

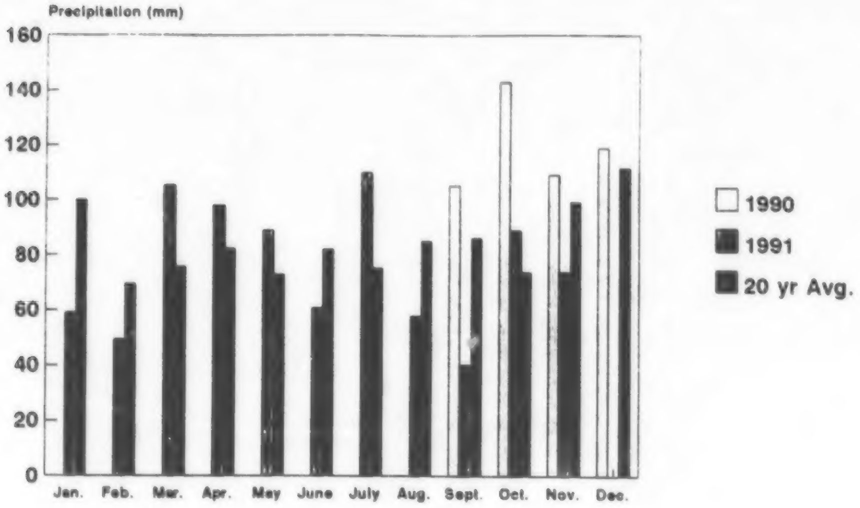


Soybean-Spring Cereal Cover Crop-Corn Management Systems
Temperature Data: Site 2

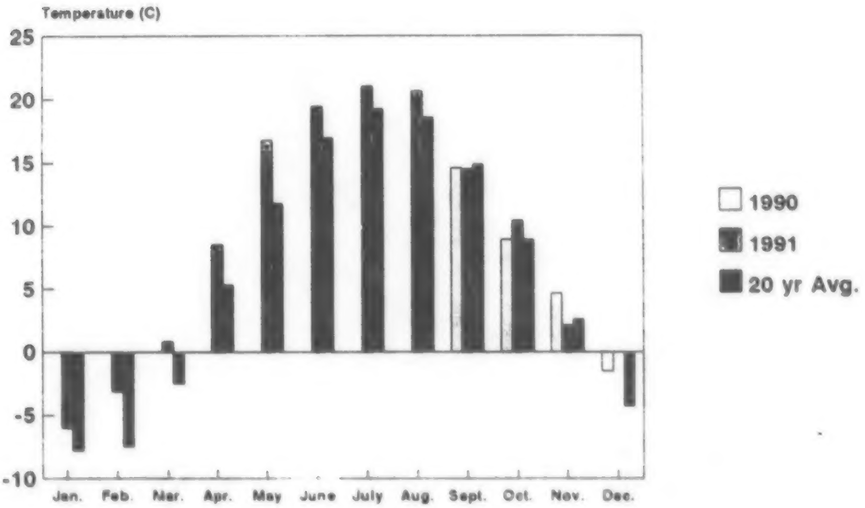


Source: Atmospheric Environment Service, Environment Canada
Exeter Weather Station

Soybean-Spring Cereal Cover Crop-Corn Management Systems
Precipitation Data: Site 3

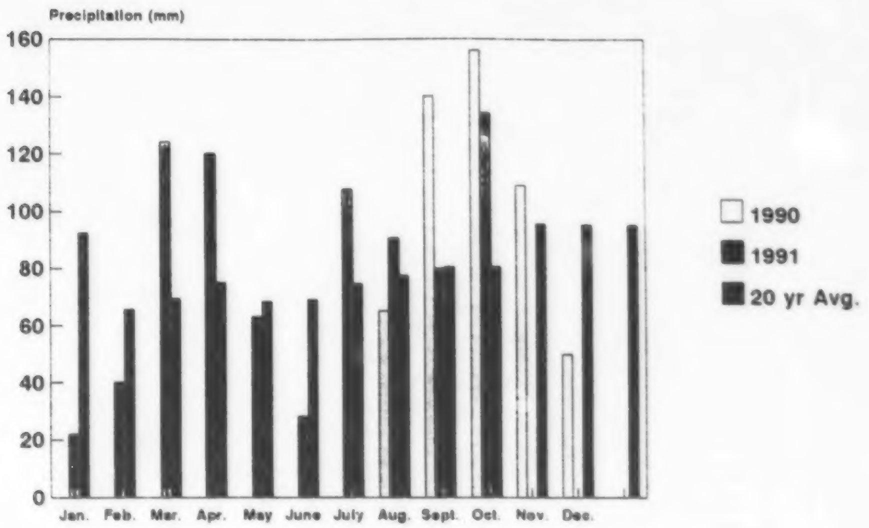


Soybean-Spring Cereal Cover Crop-Corn Management Systems
Temperature Data: Site 3

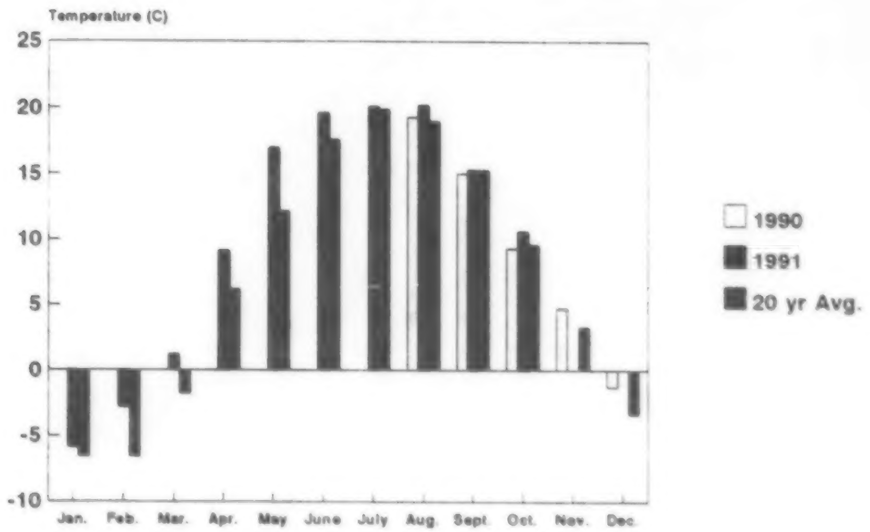


Source: Atmospheric Environment Service, Environment Canada
Stratford Weather Station

Soybean-Spring Cereal Cover Crop-Corn Management Systems
Precipitation Data: Sites 4 and 5



Soybean-Spring Cereal Cover Crop-Corn Management Systems
Temperature Data: Sites 4 and 5



Source: Atmospheric Environment Service, Environment Canada
Brucefield Weather Station

APPENDIX C

SLIDE PRESENTATION WITH WRITTEN EXPLANATION OF UNDERSEEDING COVER CROPS INTO CORN AND SOYBEANS. TO BE USED FOR EXTENSION PURPOSES.

SET #1 UNDERSEEDING ANNUAL RYEGRASS INTO CORN

SET #2 UNDERSEEDING SPRING CEREALS INTO SOYBEANS AT 10% LEAF DROP

Set #1 Underseeding Annual Ryegrass into Corn

Slide 1 The field scale studies were carried out using a Herd® Sure-Feed Broadcaster mounted on the tractor. Any type of broadcaster can be used which can either be mounted on the tractor or on the interrow cultivator depending on the producers preference.

Slide 2 The earlier you seed into corn the better - with knee height being the optimum height.

Slide 3 Example of broadcasting the seed. Recommended rate is 15 kg/ha.

Slide 4 One month after seeding, the ryegrass had already germinated and grown to 2.5-5.0 cm blades.

Slide 5 It was observed that the best germination was achieved in the slightly compacted wheel tracks which gave better soil to seed contact.

Slide 6 Two months after seeding. The annual ryegrass germination is improving but growth is not very rapid.

Slide 7 Four months after seeding. The canopy of the corn started to open up as the leaves died back which improves the growth of the annual ryegrass.

Slide 8 Weigh wagon utilized for yield checks. Results of the yield data indicate there were no significant differences in corn yield (year of cover crop establishment) or soybean yield (subsequent crop) that could be attributed to competition from the annual ryegrass.

Slide 9 Two to four weeks after harvest. The annual ryegrass really thickens up growing anywhere from 25 to 45 cm in a good moist year.

Slide 10 The following spring (mid-April). The annual ryegrass is still very prolific. It must be controlled chemically or by tillage depending on the cooperators preference.

Slide 11 Volunteer annual ryegrass may persist at light to moderate levels the following year. However it is unlikely that the annual ryegrass will be at high enough pressures to affect yield especially if control methods were adequate.

Slide 12 Some of the problems that may be associated with this method include applying the annual ryegrass when the corn is too tall which will result in broken corn stalks.

Slide 13 Example of ungerminated seeds two weeks after planting in a dry year. Annual ryegrass is not very drought tolerant, therefore in a dry year germination will be reduced.